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Why your dreams are
BIZARRE BUT BELIEVABLE

THE TRUTH ABOUT WEIGHT LOSS

The 3 rules your diet needs to actually work

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IN THIS ISSUE

Venus
How scientists discovered an active volcano on another planet

Testosterone
Why the hormone isn't a menopause wonder drug

Physics
Why it's all made up... and that's okay

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Is there anything I should avoid eating at lunch, to dodge the afternoon slump? →p75

FROM THE EDITOR

If you want to lose weight, don't look at social media. It is a bin fire of hot takes, dude bros and con artists. The latest diet craze pulling in the clicks is the carnivore diet. Supposedly, if you want to sort out your mood, energy and get pumped, you just need to cram as much minced meat, bone stock and steak into your pie hole as you can stomach.

Not a single fruit, vegetable, legume, nut, grain or seed should pass your lips, depriving you of all the fibre, antioxidants, vitamins and other nutrients (and joy!) they provide. Clearly, this is a terrible idea for your health, not to mention your gut, and indeed we've already written pieces debunking it. But I bring it up because the carnivore diet is a sign of our times; it's a measure of how poisoned the world of dieting has become.

Unfortunately, these diet trends draw their power from a world that wants to feed us. Food has never been more available, more convenient or more indulgent. Nor has it ever been so pervasive: it's advertised to us on our TVs, on billboards and in the high streets. It's become so hard to shift the pounds, that people will literally consider eating like a pet dog, in the hope of making a change. In this environment, people will inevitably try to sell easy, quick fixes to the problem of weight gain. So it begs the question, with the myriad of options out there, what does the science say about actually losing weight and keeping it off? Head to p52, where obesity expert Prof Giles Yeo reveals all.

Daniel Bennett, Editor

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CONTRIBUTORS

DR DEAN BURNETT
Riding a unicorn through a forest filled with iridescent trees? Sounds like you're dreaming. But what is actually going on in your brain? Neuroscientist Dean explains in his new column. →p32

PROF DAVID NUTT
The recreational use of laughing gas has skyrocketed, and now politicians are calling for tighter regulation. Neuropsychopharmacologist David breaks down its effects, legal status and risks. →p36

PROF GILES YEO
BBC presenter Giles studies how your brain and genetics control your body weight. In this issue, he looks at what we actually know about successful diets. →p52

DR LOUISA PRESTON
The JUICE mission blasts off to explore Jupiter's moons this month. Astrobiologist Louisa gives us the lowdown on what sort of life could be lurking there. →p66

ON THE BBC THIS MONTH...

Dementia: Unexpected Stories Of The Mind
In this short-form five-part series, a neurologist visits the homes of patients with rare forms of dementia to explore the varying natures of the condition and its causes.
BBC Radio 4,
10 April, 1:45pm

Deep Waters: The Hidden World Of Global Shipping
Okay, a radio show about shipping might be a hard sell, but logistics makes the world go round. In this episode we meet a salvage man who discovers shipping crates that get left behind, cracks them open and then makes millions from what's inside.
BBC World Service,
9 April, 10pm
Also available on BBC Sounds

Just One Thing
Michael Mosley is back with his tips for better living. This time it's something that's close to our hearts: writing. Tune in to find out about how a technique called 'expressive writing' can be good for you.
Available now on BBC Sounds

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CONTENTS

REGULARS

06 EYE OPENER
Incredible pictures that'll change your view of the world.

12 CONVERSATION
See what's dropped into our inbox this month.

15 DISCOVERIES
Volcanic activity spotted on Venus for the first time; neuroscientists map the entire brain of an insect; wild rats in New York are infected with COVID-19; revolutionary gene-editing technique restores vision in mice; compounds essential for life found on near-Earth asteroid; a good night's sleep boosts effectiveness of vaccination; macaques create stone shards when making tools, just like early humans; all you need to know about the IPCC report; new spacesuit for moonwalks revealed.

30 DR KATIE MACK
Yes, everything in physics is made up, but that's okay!

32 DR DEAN BURNETT
Why the weirdest dreams seem totally normal when you're snoozing.

34 DR KATE DARLING
Should you trust an AI with your mental health?

36 REALITY CHECK
The science behind the headlines: Why do politicians want to make laughing gas illegal? Is testosterone a menopause wonder drug? Can positive affirmations improve your life?

43 INNOVATIONS
The latest tech and gadgets tested.

75 Q&A
Our experts answer this month's questions. What is a dormant black hole? Why can't robots on Mars clean themselves? How incognito is incognito mode on your internet browser?

82 EXPLAINER
Everything you wanted to know about phobias.

88 CROSSWORD
Engage your grey matter!

88 NEXT MONTH
A sneak peek at the next issue.

90 POPCORN SCIENCE
Could we feel emotions like Mantis from *Guardians Of The Galaxy*?

50
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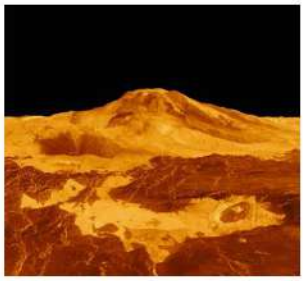
15
DISCOVERIES



For the first time, scientists have spotted hints of volcanic activity on our planetary neighbour.

36
REALITY CHECK

Why do politicians want to make laughing gas illegal, and how dangerous is it?

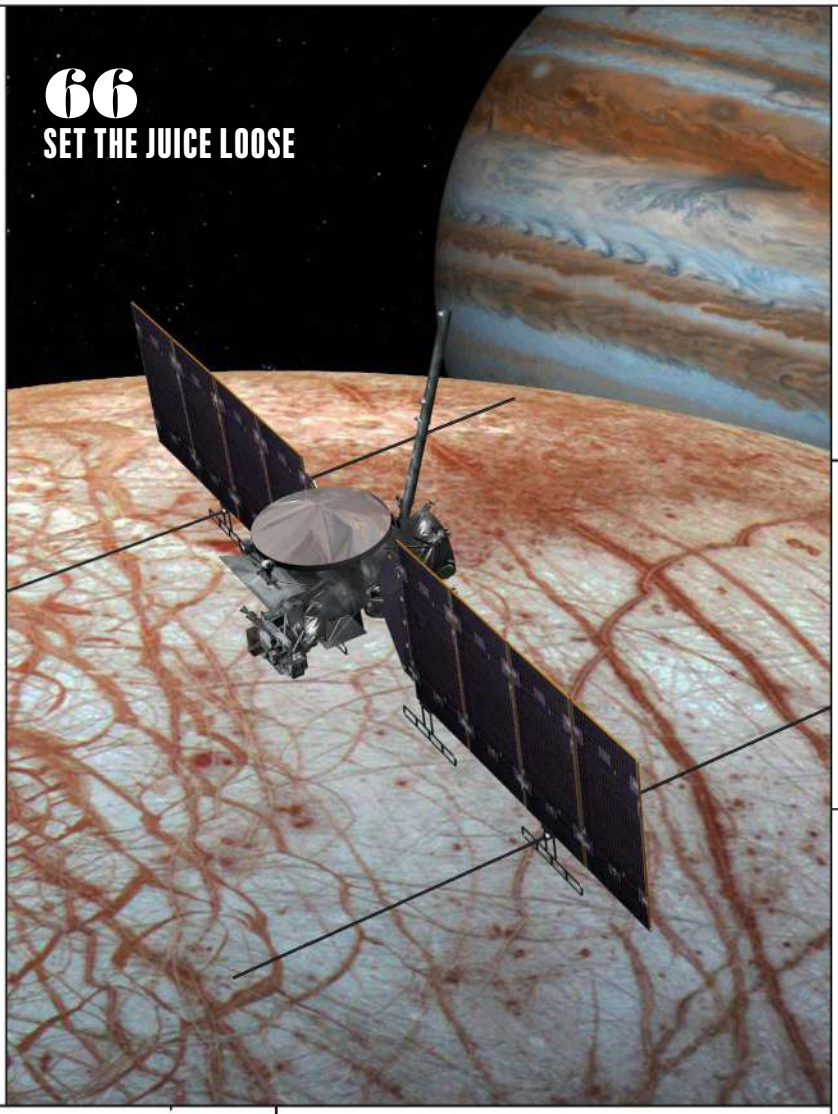
75
Q&A

FEATURES

52 3 RULES BEHIND EVERY DIET THAT WORKS
Fed up with reading dodgy dieting advice online? We asked obesity expert Prof Giles Yeo to tell us what really works.

58 DOWN ON THE ROBOT FARM
In some parts of the world, it's a struggle to recruit agricultural labourers to help with weeding, harvesting and ploughing. Could farmbots help meet the demands?

66 SET THE JUICE LOOSE
This month, after many delays due to the COVID-19 pandemic, the JUICE spacecraft is finally setting off on its trip to Jupiter. Its mission? To explore the gas giant's icy moons and find out if they're suitable for life.



66
SET THE JUICE LOOSE

48
IDEAS WE LIKE
An electric pizza oven that you can use indoors.

52
PROF GILES YEO

"ANY FOODS OR SUPPLEMENTS THAT CLAIM TO HELP 'DETOX' YOUR BODY ARE RED FLAGS"

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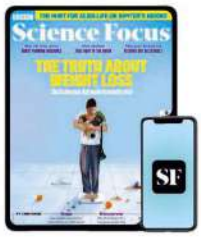

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EYE OPENER

Smoothly does it

BOLZANO, ITALY

Nestled amidst the majestic Alpine mountains in the town of Bolzano, Italy, lies the Sant'Antonio hydroelectric plant; a subterranean engineering marvel that harnesses the power of nature to produce sustainable energy. The cavernous basin pictured here is a vital part of the hydroelectric plant; it controls the flow of water and manages the release of energy in the turbine system. With a capacity of 95,000m^3, it works by slowing down the flow of water, allowing any excess energy to dissipate, preventing pressure surges that could damage the turbines or other equipment. This process, known as 'demodulation', allows the system to compensate for variations in water flow caused by changes in power demand, or fluctuations in the natural supply. Without the basin, rapidly increasing and decreasing water flow can have negative impacts on the river, including riverbank erosion, changing water temperature and oxygen levels, and fish displacement.

LUIGI AVANTAGGIATO

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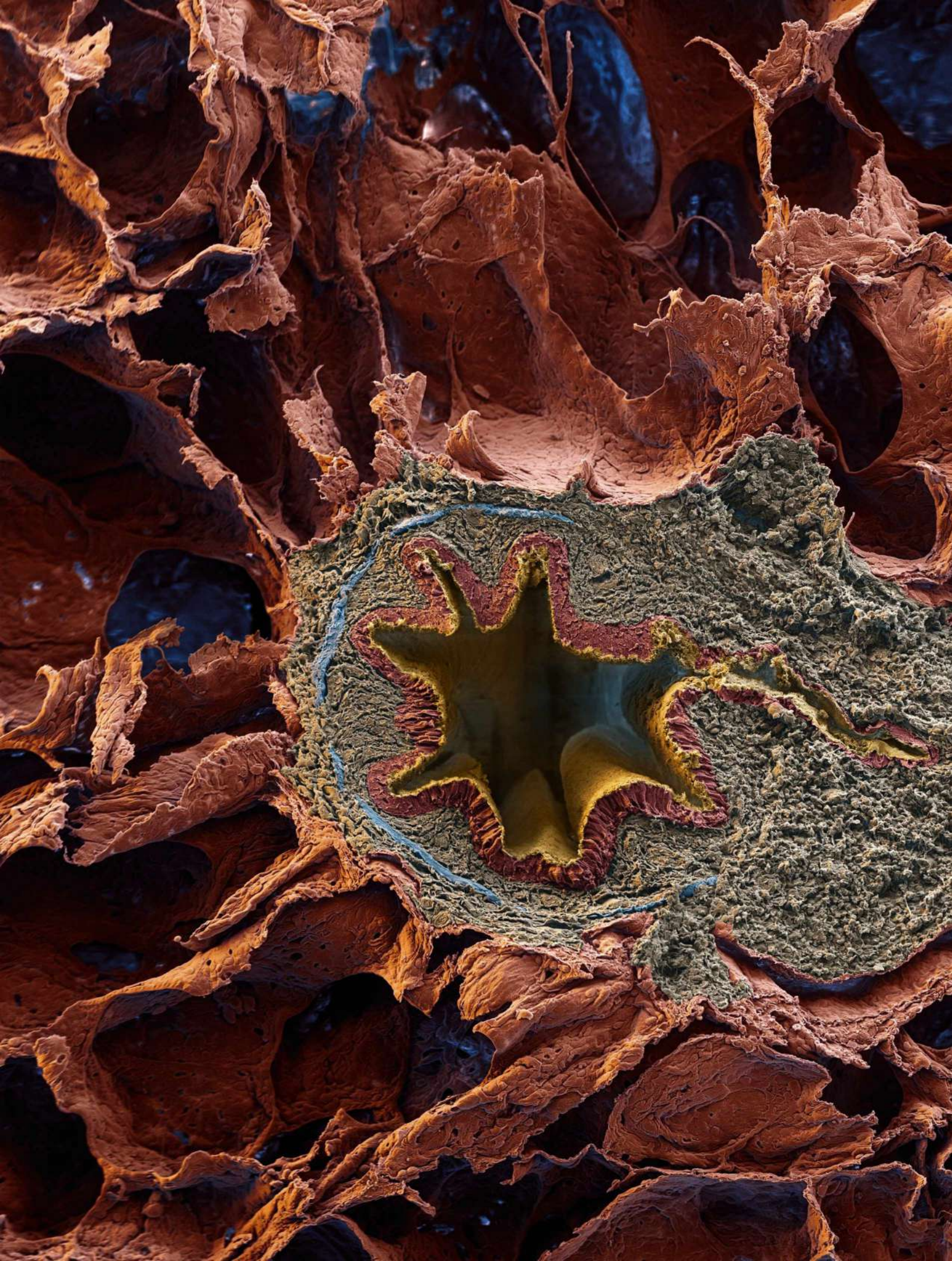

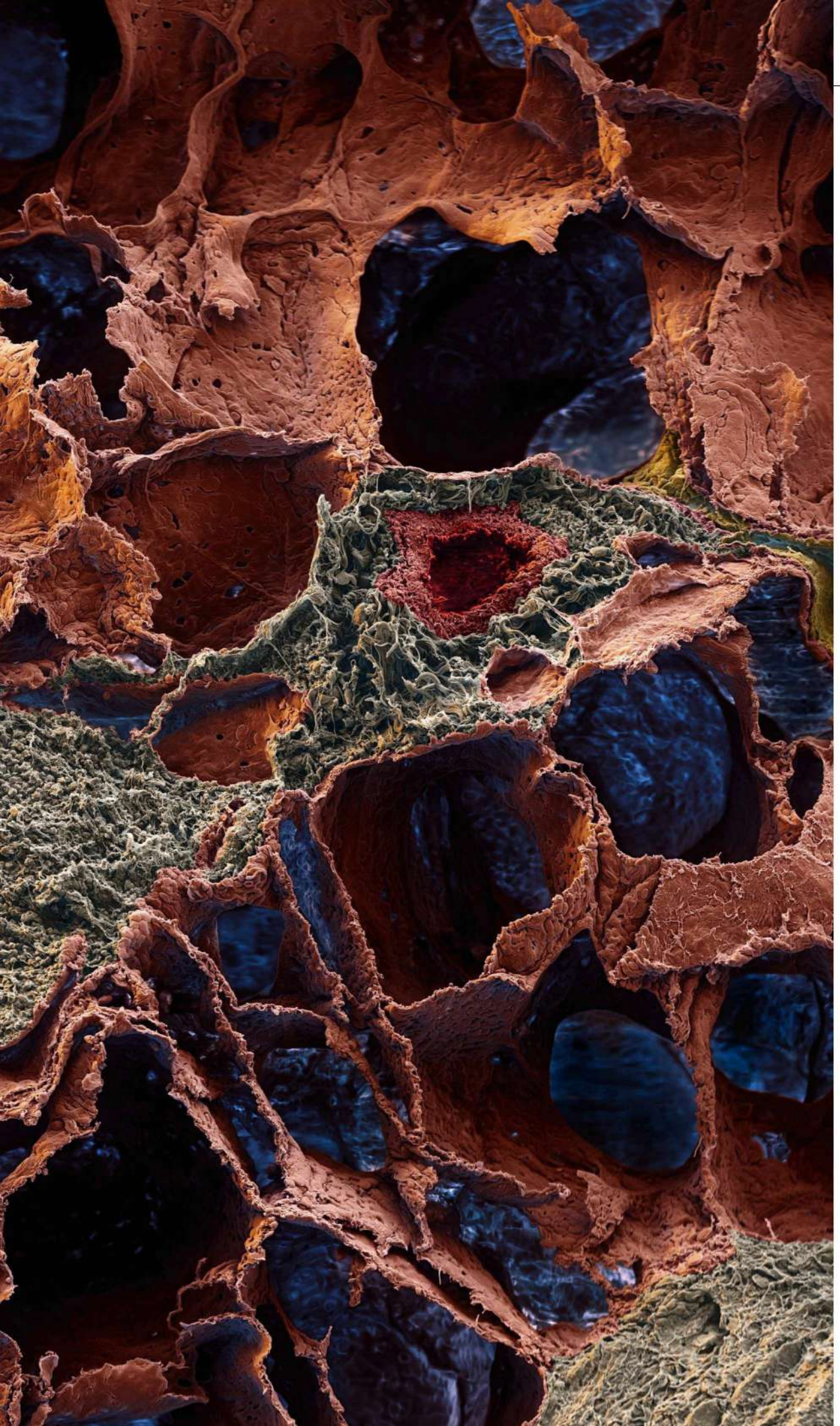

EYE OPENER

We be-lung together

At first glance, this image may look like a close-up of a freshly-baked loaf of sourdough. But it's actually a coloured scanning electron micrograph (SEM) of a section through a healthy human lung.

The yellow star-shaped feature in the centre is a bronchus, an air passage which carries air into the lungs. Grey connective tissue surrounds the bronchus, while a red artery can be seen to the right of centre.

The surrounding hollows are alveoli; tiny, balloon-shaped structures that facilitate the exchange of gases between the air and the bloodstream. Oxygen from inhaled air is taken up by the blood, and carbon dioxide – the waste product – is removed from the body during the exhale. If the body did not get rid of carbon dioxide, it would build up in the bloodstream, leading to headaches, dizziness, confusion, and shortness of breath. In severe cases, it can lead to respiratory failure – and even death.

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EYE OPENER

Eye spy

MANA POOLS, ZIMBABWE

This image of a Nile crocodile lurking in the thick mud at Mana Pools National Park in Zimbabwe was recently awarded the top prize at the World Nature Photography Awards.

According to photographer Jens Cullman, there had been a lack of rain during the wet season, so a lot of the water in the region had dried out, leaving muddy pools behind.

"I had to be very careful not to disturb the crocodile, even though it was buried in dry mud," says photographer Jens Cullman. "They will launch themselves with tremendous speed and power at any animal foolish enough to come too close."

Nile crocodiles are native to freshwater habitats on the African continent. Their eyes, nostrils and ears are positioned on top of their head, enabling them to stay submerged for hours with only the top of their head exposed. The eyes have a translucent nictitating membrane, which is just about visible in the inner corner of the crocodile's eye in this image. This is drawn across the eye when the animal is underwater to protect the eyeball surface, while allowing some degree of vision.

JENS CULLMANN/WNPA

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

Responsibility for AI

Dr Kate Darling's commentary on the responsibilities of the creators of AI applications (February, p34), is really no different to a parent's responsibility towards the education of their children. If you decide to educate your child by allowing them to get all their education from randomly surfing the internet, then the result would be akin to child neglect. No parent would be allowed to claim that they are in no way responsible for their child's misdirected education. An AI application is still just a computer program, and it is down to the developers to ensure that it learns sensibly, in the same way that a parent would ensure that their child is educated correctly.

Nigel Jarvis, via email

I agree! We hold guardians accountable for the miseducation and misbehaviour of children or pets. I might also add that the child doesn't 'grow up' in the case of AI. AI systems require constant monitoring, and they should remain the responsibility of the humans or corporations that deploy them.

Dr Kate Darling, *BBC Science Focus* columnist

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **Wi-Fi 6 Repeater 5400** from Devolo. The device provides efficient emergency relief when the Wi-Fi signal is weak, and extends limited signal even to your favourite corner that's far away from the router! With transmission speeds of up to 5,400Mbps, it will help supply your phone, laptop and other devices with rapid Wi-Fi. **devolo.co.uk**

ALAMY

THE VENUS-JUPITER CONJUNCTION

We loved seeing your photos of the astronomical event

↑ Saltsburg, Pennsylvania

I read your web article about the Venus-Jupiter conjunction. I was sad to read that it was cloudy in the UK [before their closest approach], so I decided to send a photo of what I saw from Saltsburg, Pennsylvania, USA, 21 February 2023. This image of the conjunction includes the Moon, along with Venus and Jupiter, taken on a rare, relatively clear winter night, at around 6:40pm from behind the John A. Pidgeon library at the Kiski School in Saltsburg, Pennsylvania. It was taken using a handheld Samsung Note 20 cellphone.

Mark Orsatti, via email

"THE USE OF ANECDOTES RATHER THAN EVIDENCE DEVALUES THE IMPORTANCE OF SCIENTIFIC DATA IN WOMEN'S HEALTH AND IS AT THE CORE OF A GROWING PROBLEM"

DR MICHELLE GRIFFIN, P39

← Edinburgh, UK

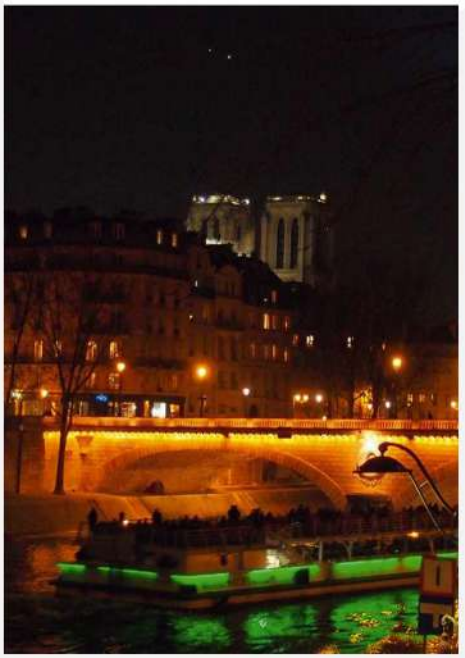
The astronomically rare conjunction of Venus, Jupiter and Gilbert.

Keith Matthews, via Twitter

↓ Paris, France

The conjunction of Venus and Jupiter on 1 March 2023 is seen right above the twin towers of the Cathédrale Notre-Dame de Paris and the Bridge of Louis Philippe, France.

Yassir Abdulfatah, via email



← Cape Point, South Africa

We live at Cape Point in South Africa, and due to our remoteness and ongoing loadshedding [widespread electricity blackouts], are able to view a pretty impressive sky with colourful sunsets. We were able to snap some pictures on 22 February with the crescent Moon. I only used my phone camera, so the pictures are not good resolution and the Moon is blurred, but they aren't enhanced in any way.

Nicole Dale, via email

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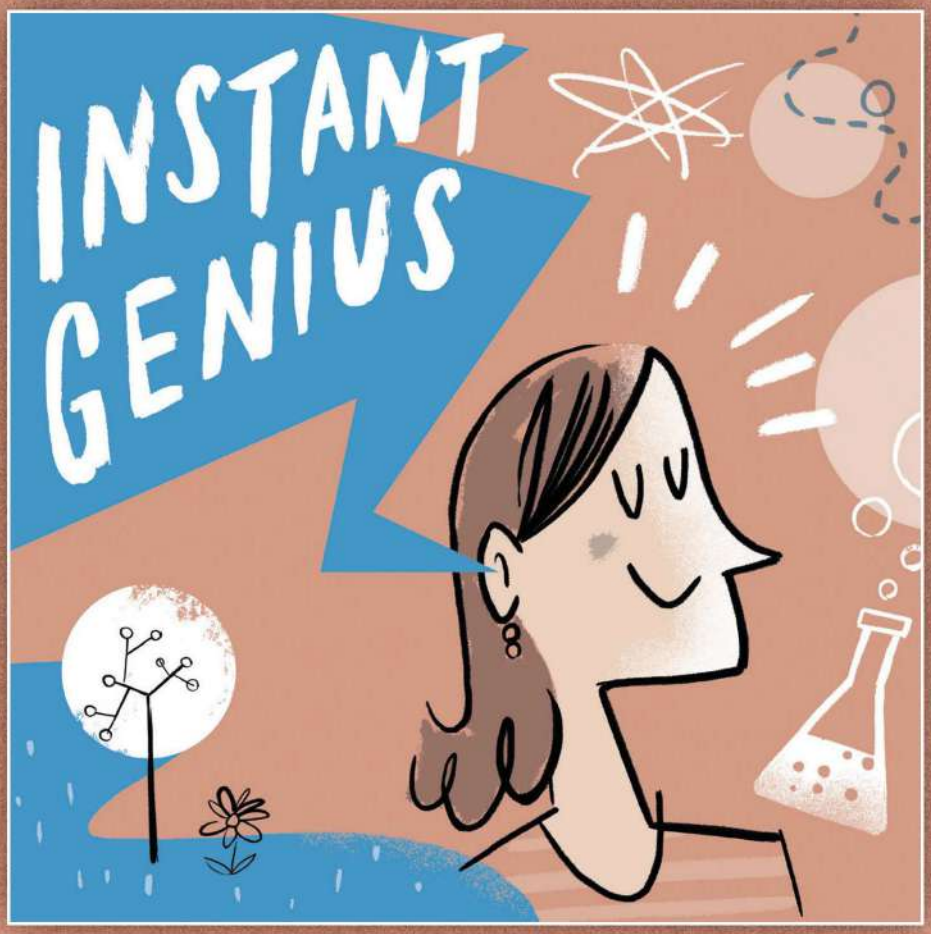


FEATURING

SEASHELLS
with ***Dr Helen Scales***

BEE COGNITION
with ***Prof Lars Chittka***

LIFE ON MARS
with ***Lewis Dartnell***

ARTEMIS
with ***Libby Jackson***

DISCOVERIES

"The ability to make sharp stone flakes is a crucial point in the evolution of hominins'"

Dr Tomos Proffitt **p23**

SPACE

VOLCANIC VENUS

New lava flows spotted on Venus's surface **p16**

NEUROSCIENCE

MIND MAP

Complete circuitry of insect brain mapped for first time **p18**

HEALTH

OH, RATS!

Rats in New York's sewers have tested positive for coronavirus **p19**

BIOLOGY

THESE UNBLIND MICE

Vision restored in mice using gene-editing technique **p20**

SPACE

ALIEN VITAMINS

The Hayabusa2 mission has gathered vitamin B3 and uracil (a component of RNA) from the asteroid Ryugu **p21**

MEDICINE

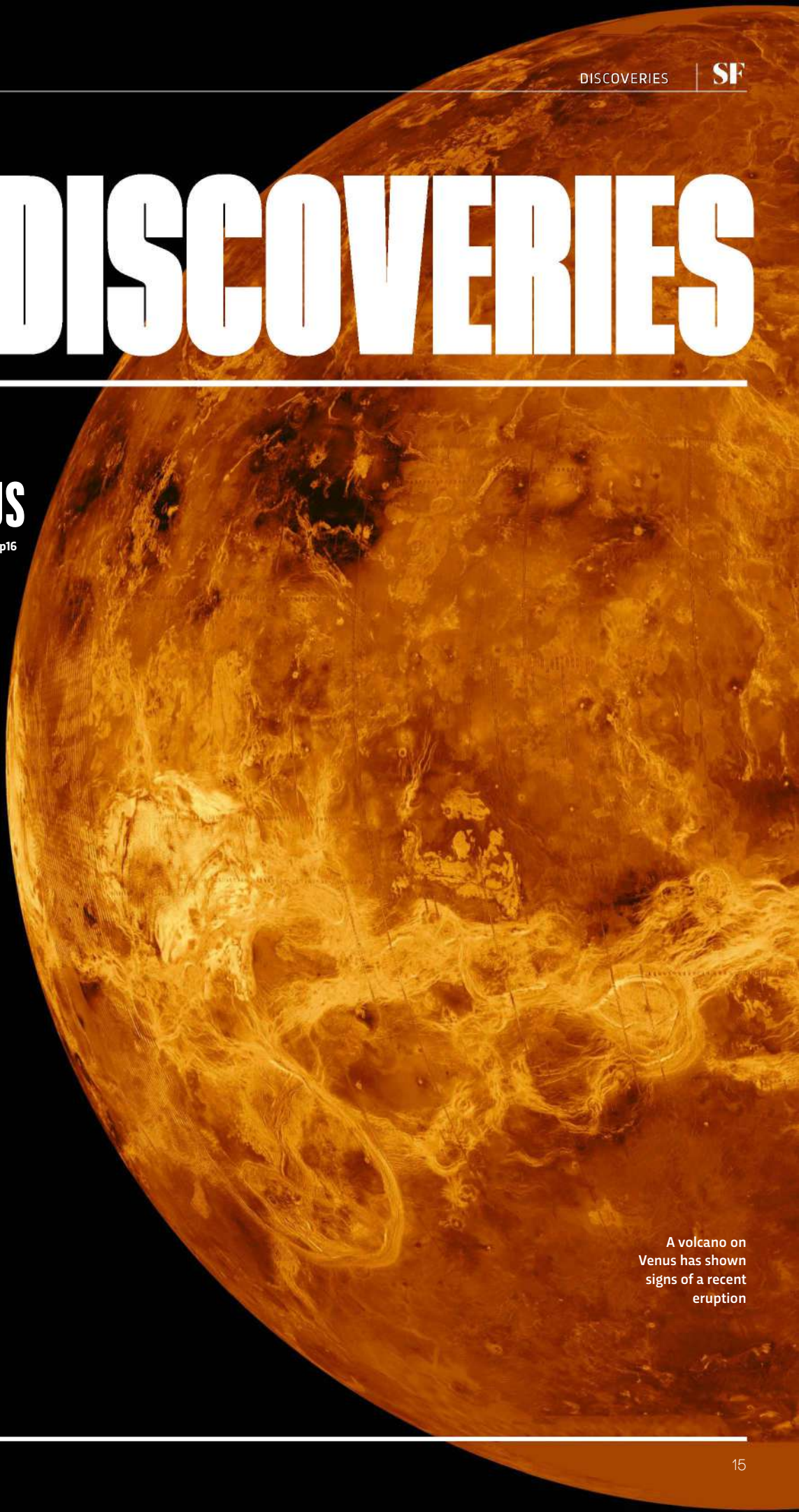
SLEEP YOURSELF WELL

People who sleep for longer after vaccinations produce a better immune response **p22**

ANTHROPOLOGY

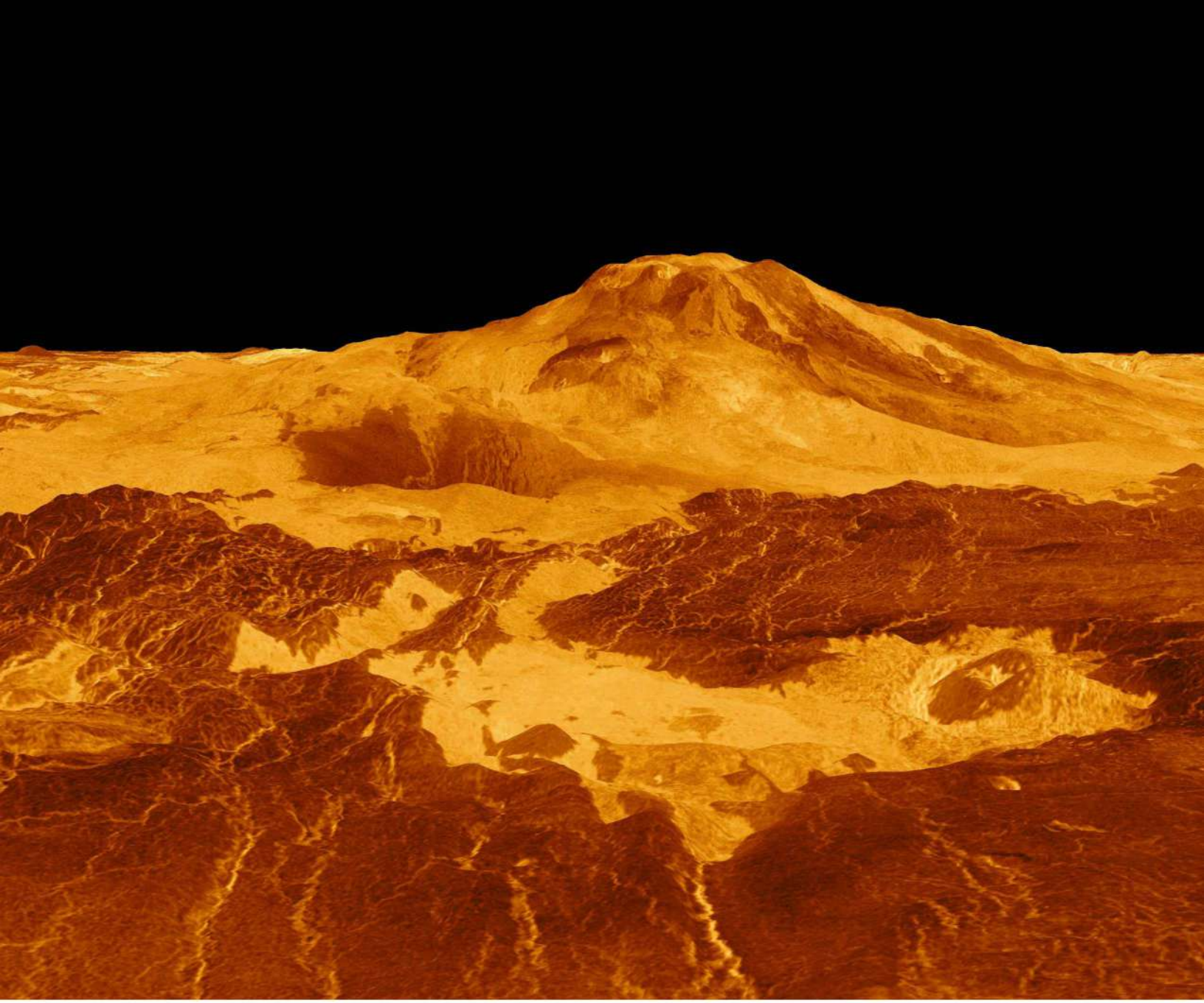
MONKEY BUSINESS

Long-tailed macaques in Thailand make stone shards similar to those created by early humans **p23**



A volcano on Venus has shown signs of a recent eruption

NASA/JPL-CALTECH



SPACE

SIGNS OF VOLCANIC ACTIVITY FOUND ON VENUS FOR THE FIRST TIME

Images taken by the Magellan space probe in the 1990s could show evidence of eruptions or magma flow

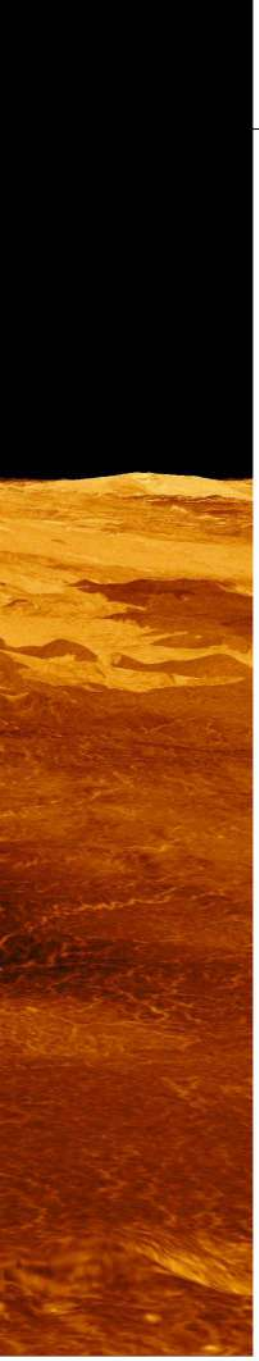
ABOVE Computer-generated 3D model of Maat Mons on Venus, where there is evidence of volcanic activity

Volcanic eruptions and magma flows could be taking place on the surface of Venus, researchers from the University of Alaska Fairbanks Geophysical Institute have found.

The team studied data collected by NASA's Magellan space probe in the 1990s, taking advantage of new techniques that allow them to compare digital images more efficiently.

Their analysis focused on an area containing two of Venus's largest volcanoes, Ozza Mons and Maat Mons. They discovered a roughly 2.5km^2 volcanic vent that changed shape and altered in size over a period of eight months in 1991 on Maat Mons. On Earth, changes of this magnitude are often indications of volcanic activity.

"It is really only in the last decade or so that the Magellan data has been available at full resolution, mosaicked and easily manipulable by an investigator with a typical personal workstation," said Robert



NASA/JPL-CALTECH, ROBERT R HARRICK/SCOTT HENSLEY/SCIENCE X2

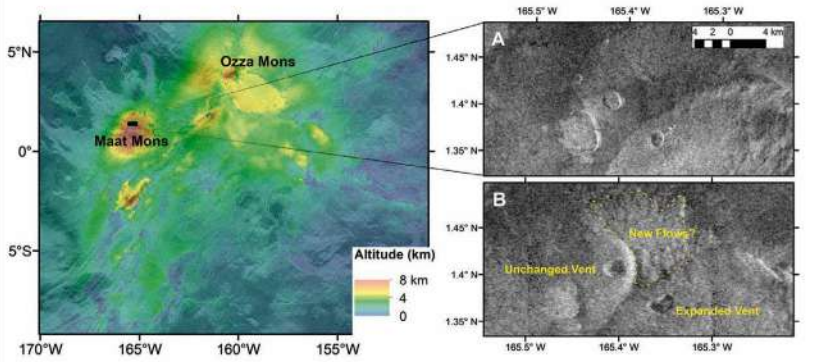
Ask the expert

Was this discovery unexpected?

This is big. We've long suspected that Venus is volcanically active, but we've not had any direct evidence of such activity – until now. I think it's fair to say that this finding isn't unexpected. This kind of collapse/eruption takes place on Earth regularly, at least geologically speaking. And Venus has lots and lots and lots and LOTS of volcanic landforms – volcanoes, calderas, vents – and flows. But it's one thing to expect something and quite another to then actually see it.

Does this discovery mean we are more likely to find volcanic activity on other planets or moons?

This finding doesn't have any bearing on finding active volcanism on any other body. What it does do is make it very likely that we'll see more evidence for ongoing volcanic activity elsewhere on Venus, either by continuing to look through the Magellan data, or with the new radar data we'll get from the VERITAS and EnVision missions in the 2030s.



What other research is ongoing in this area?

Right now, I expect that people are starting to look at maps of Venus themselves to see if they can spot additional evidence for changes in Magellan data. There's other work to calculate how volcanic activity works on Venus, along with modelling to figure out what we might see with the higher-resolution data we'll get from those future missions.

What can we expect to discover in the future?

Going forward, we're going to learn a lot more about how active Venus is – not just volcanically, but also tectonically, and in terms of wind-blown erosion, landslides, you know it. There has long been a view that Venus isn't all that active a place, even though it's almost the same size as Earth, which is a very active world. This new view of an active Venus is becoming more and more prevalent, and this new paper has definitely moved the needle in that direction in a huge way.

PROF PAUL BYRNE

Paul is an associate professor of earth and planetary science at Washington University in St Louis. His research focuses on what makes planets behave and look the way they do. He uses remotely sensed data, fieldwork here on Earth, and numerical and physical models to build a better understanding of our planet and alien worlds.

"Venus is volcanically active in the sense that there are at least a few eruptions per year"

Herrick, a research professor at the University of Alaska Fairbanks, who led the research. "Ozza and Maat Mons are comparable in volume to Earth's largest volcanoes, but have lower slopes and thus are more spread out."

The researchers compared two images of the northern side of a domed shield volcano that is part of Maat Mons, one taken in February 1991, and one taken in October 1991. Over this period, the vent had changed from a circular shape of around 2.5km^2 to a wobbly shape of around 3.75km^2. This later image shows that the walls of the vent became shorter, indicating an eruption, and that the irregular shape was formed by magma flows during the eight months between the images.

There is one small caveat: the shape of the vent's walls may have been caused by an earthquake, the researchers say. However, on Earth, vent collapses on this scale are always accompanied by nearby volcanic eruptions.

"We can now say that Venus is presently volcanically active in the sense that there are at least a few eruptions per year," said Herrick. "We can expect that the upcoming Venus missions will observe new volcanic flows that have occurred since the Magellan mission ended three decades ago, and we should see some activity occurring while the two upcoming orbital missions are collecting images."

NEUROSCIENCE

COMPLETE CIRCUITRY OF AN INSECT BRAIN MAPPED FOR THE FIRST TIME

The model shows every single neuron and connection in the brain of a fruit fly larva

Researchers at the University of Cambridge have pieced together a map showing every single neuron and how they're wired together in the brain of a fruit fly larva.

The map shows all 3,016 of the neurons in the larva's brain and the complex network of 548,000 synapses – known as the connectome – that carry chemical signals between them. It is the biggest map of its kind ever produced. The researchers hope that the map will enable them to study how signals travel through the brain and affect learning and behaviour.

"The way the brain circuit is structured influences the computations the brain can do," said co-researcher Prof Marta Zlatic of the Medical Research Council Laboratory of Molecular Biology.

Until now, scientists have only seen the brain structure of simpler animals, including a roundworm, the larva of a marine segmented worm, and the larva of a sea squirt, all of which only have several hundred neurons.

"This means neuroscience has been mostly operating without circuit maps. Without knowing the structure of a brain, we're guessing on the way computations are implemented. But now we can start gaining a mechanistic understanding of how the brain works," Zlatic added.

The team produced the image by scanning thousands of slices of the larva's brain using a high-resolution electron microscope and painstakingly marking out the connections between the neurons. They now plan to delve deeper into the map to study the structures involved with specific functions such as learning and decision-making. Although the current technology isn't sophisticated enough to map out mammal brains, there is still much to learn.

"All brains are similar – they are all networks of interconnected neurons – and all brains of all species have to perform many complex behaviours: they all need to process sensory information, learn, select actions, navigate their environments, choose food, recognise their conspecifics and escape from predators," said Zlatic. "In the same way that genes are conserved across the animal kingdom, I think that the basic circuit motifs that implement these fundamental behaviours will also be conserved."

86BN

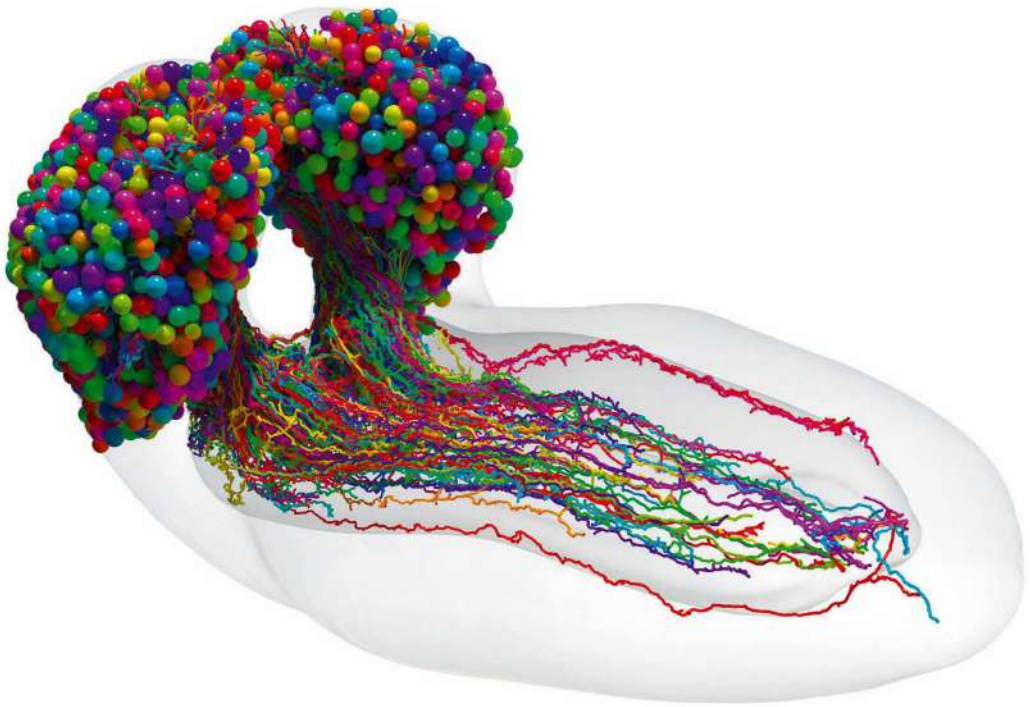
The average number of neurons in a human brain

60%

The proportion of the human brain that's made up of fat. This makes it our fattiest organ

425KM/H

The speed at which electrical signals travel between brain cells



BELOW Nope, not a huge bunch of party balloons, but a complete map of the neurons within the brain of a fruit fly larva

JOHNS HOPKINS UNIVERSITY/UNIVERSITY OF CAMBRIDGE, GETTY IMAGES

LEFT Brown rats in New York have tested positive for COVID, but we don't yet know if they can spread the disease to humans

HEALTH

WILD RATS LIVING IN NEW YORK CITY SEWERS ARE CARRYING CORONAVIRUS

More than 15 per cent of rats captured in wastewater systems tested positive for the virus

According to a study carried out by researchers at the University of Missouri, a significant proportion of rats living in the New York municipal sewer systems are infected with SARS-CoV-2.

The team carried out two trapping sessions in the autumn of 2021 to round up wild brown rats (*Rattus norvegicus*) in areas surrounding wastewater systems in city parks within Brooklyn. Of the 79 rats they captured, 13 tested positive for COVID – that's around 16 per cent.

In a separate experiment carried out within the laboratory, the researchers also found that coronavirus variants carried by humans, namely Alpha, Delta and Omicron, can cause infections in Sprague Dawley rats, a breed of albino rat often used in medical research.

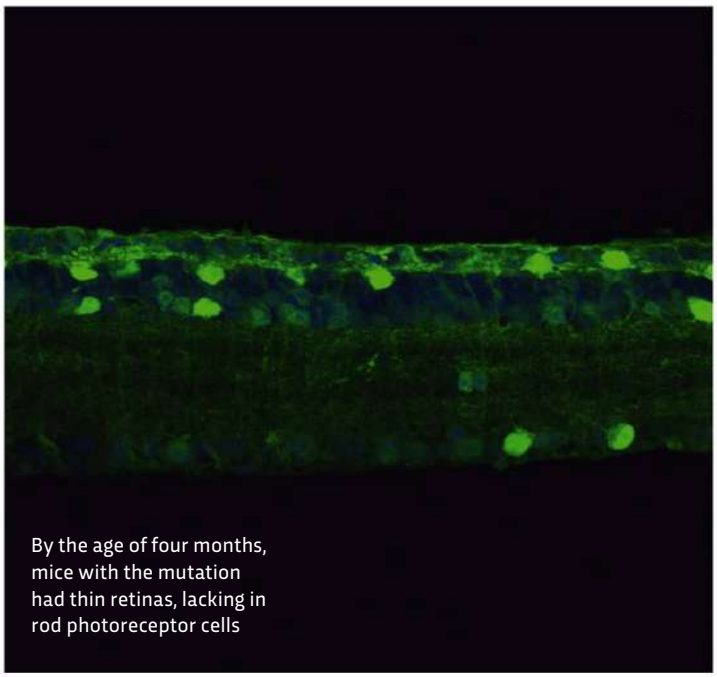
After infection, they found high levels of the viruses in the animals' upper and lower respiratory tracts. However, it's not yet clear if the rats are spreading the disease to humans.

"To the best of our knowledge, this is one of the first studies to show SARS-CoV-2 variants can cause infections in the wild rat populations in a major US urban area," said Prof Henry Wan, director of the Center for Influenza and Emerging Infectious Diseases at the University of Missouri.

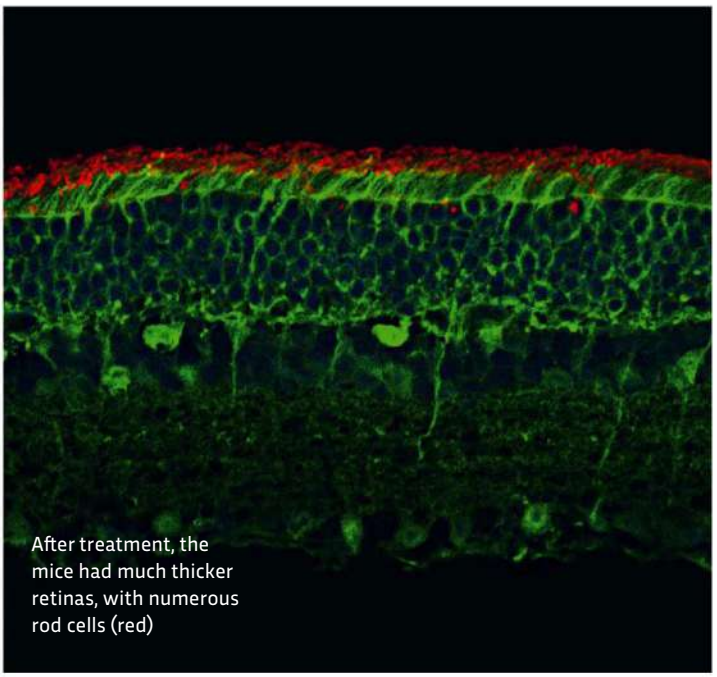
"Overall, our work in this space shows that animals can play a role in pandemics that impact humans, and it's important that we continue to increase our understanding so we can protect both human and animal health."

Rats are a common site in many urban areas around the world, New York City is home to around eight million, meaning they frequently come into contact with humans. Further studies are essential to investigate how rats infect one another and how they could help to spread the virus among humans, the researchers say.

"Our findings highlight the need for further monitoring of SARS-CoV-2 in rat populations to determine if the virus is circulating in the animals and evolving into new strains that could pose a risk to humans," said Wan.



By the age of four months, mice with the mutation had thin retinas, lacking in rod photoreceptor cells



After treatment, the mice had much thicker retinas, with numerous rod cells (red)

BIOLOGY

VISION LOSS RESTORED IN MICE USING REVOLUTIONARY GENE-EDITING TECHNIQUE

Mice treated with CRISPR-based technique retained their vision well into old age

Researchers in China have successfully restored the vision of mice with an inherited condition that leads to blindness.

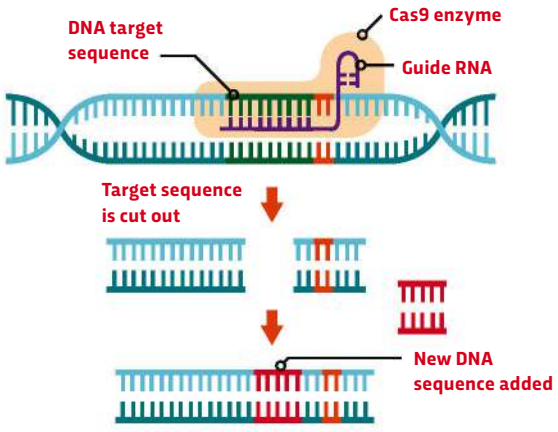
The team, who are based at the Wuhan University of Science and Technology, used a newly developed CRISPR-based gene-editing technique to restore the sight of mice with retinitis pigmentosa. The disease can be caused by mutations in more than 100 different genes. It causes photoreceptive cells in the retina to break down slowly over time, leading to vision loss and ultimately to blindness. It currently affects more than 1 in 4,000 people.

HOW DOES CRISPR WORK?

1. Scientists create a genetic sequence called a 'guide RNA' that matches the DNA they want to target.

2. This sequence is added to a cell along with the Cas9 enzyme, which acts like a pair of scissors to snip off the target sequence after the guide RNA has homed in on it.

3. Once their jobs are complete, the guide RNA and Cas9 leave the scene and the new DNA sequence can be added.



Gene-editing techniques have been used to restore vision in mice with genetic diseases, but only those that affect cells linked to the photoreceptors, not the photoreceptors themselves.

"The ability to edit the genome of neural retinal cells, particularly unhealthy or dying photoreceptors, would provide much more convincing evidence for the potential applications of these genome-editing tools in treating diseases such as retinitis pigmentosa," said Kai Yao, a professor at the Wuhan University of Science and Technology.

The researchers targeted a mutation in the gene encoding an enzyme called PDE6β using a newly developed CRISPR-based system called PESpRY. This can be programmed to correct many different types of mutation by cutting out specific sequences of DNA at any point on the genome.

By targeting the mutant gene, the researchers were successfully able to restore the enzyme's normal function and prevent the death of the mice's photoreceptors. The mice treated retained their vision into old age and were able to navigate their way out of mazes almost as effectively as healthy mice.

Although the study was a success, more work needs to be done before the system can be trialled in humans, the researchers say.

QIN ET AL, JAXA, GETTY IMAGES

SPACE

COMPOUNDS ESSENTIAL FOR LIFE FOUND IN SAMPLES COLLECTED FROM A NEAR-EARTH ASTEROID

Samples collected during Hayabusa2's trip to the asteroid Ryugu contain uracil, a substance present in RNA

Organic compounds essential for life have been discovered in samples collected from a distant asteroid by Japan's Hayabusa2 Spacecraft.

The compounds discovered include niacin, which is also known as vitamin B3, and uracil, one of the four nucleobases. Nucleobases are nitrogen-containing compounds that make up RNA, which is a molecule present in all living cells and has structural similarities to DNA.

"Scientists have previously found nucleobases and vitamins in certain carbon-rich meteorites, but there was always the question of contamination by exposure to the Earth's environment," said lead researcher Prof Yasuhiro Oba, of Hokkaido University.

"Since the Hayabusa2 spacecraft collected two samples directly from the asteroid Ryugu and delivered them to Earth in sealed capsules, contamination can be ruled out."

Hayabusa2 was launched in December 2014 by the Japanese space agency JAXA. It reached its target, the space rock Ryugu, in June 2018, stayed for a year and a half to gather samples, and returned them to Earth in December 2020.

> "The finding adds further credence to the theory of panspermia"

The team extracted the compounds by soaking samples taken from Ryugu in hot water and analysing them with a high-resolution mass spectrometer. As well as uracil and niacin, they also found several other biologically important molecules, including a selection of amino acids, amines and carboxylic acids, which are found in proteins and play a role in the metabolism of living things.

The compounds likely formed from simpler molecules such as ammonia, formaldehyde and hydrogen cyanide, which are all commonly found in cometary ice, the researchers say.

The finding adds further credence to the theory of panspermia – the hypothesis that important building blocks for life are created in space and could have been brought to Earth by meteorites.

"The discovery of uracil in the samples from Ryugu lends strength to current theories regarding the source of nucleobases in the early Earth," said Oba.

"The OSIRIS-REx mission by NASA will be returning samples from asteroid Bennu this year, and a comparative study of the composition of these asteroids will provide further data to build on these theories."

MEDICINE

GETTING A GOOD NIGHT'S SLEEP IMPROVES IMMUNE RESPONSE TO VACCINATIONS

People who sleep for less than six hours a night produce significantly fewer antibodies after getting their jabs

It's well established that sleep is vital for our health – it reduces the risk of everything from heart disease and stroke to obesity and dementia. Now, a study by researchers in Paris, France, and Chicago, USA, has found that getting a good night's sleep can also help our bodies' immune response to vaccinations.

To investigate the effect of sleep on vaccine effectiveness, the team combined the results of seven studies looking at jabs for influenza and hepatitis A and B. They then compared the antibody responses of the participants who slept for seven to nine hours a night with those who slept for six hours or less.

"We're going to be vaccinating millions of people in the next few years and this can help maximise protection"

In each study, the participants' sleep was measured in a lab, at home using a sleep-tracking smartwatch, or was self-reported by the participants.

The researchers found that sleeping for less than six hours per night significantly reduced immune response to vaccination. However, the difference was most prominent in men and, according to the study, this could be due to women's fluctuating sex hormones.

"We know from immunology studies that sex hormones influence the immune system," said lead researcher Karine Spiegel, from the French National Institute of Health and Medical Research.

GETTY IMAGES, LYDIA V LUNCZ

SLEEP FACTS

The longest time a human being has gone without sleep is 11 days and 25 minutes. The record was set by 17-year-old American Randy Gardner in 1963.

If it takes you less than five minutes to fall asleep, you're likely to be sleep deprived. Ideally, it should take you 10-15 minutes.

For most people tiredness peaks twice a day – once at 2am and then again at 2pm.

ABOVE LEFT Vaccinations appear to have a better effect when followed by a good night's sleep

"In women, immunity is influenced by the state of the menstrual cycle, the use of contraceptives, and by menopause and post-menopausal status, but unfortunately, none of the studies that we summarised had any data about sex hormone levels."

The negative effect was also more pronounced in those aged 18 to 60 compared to the over-65s. This is likely due to older people tending to sleep less.

While there is still more to be investigated about the relationship between sleep and vaccination, knowing that the two are linked could help people make lifestyle choices to optimise their immunity, the researchers say.

"We need to understand the sex differences, which days around the time of vaccination are most important, and exactly how much sleep is needed so that we can give guidance to people," said Spiegel.

"We are going to be vaccinating millions and millions of people in the next few years, and this is an aspect that can help maximise protection."

ARCHAEOLOGY

STONE SHARDS MADE BY THAI MONKEYS ARE SIMILAR TO THOSE MADE BY EARLY HUMANS

The discovery may point to the origins of human tool use

Shards of stone produced by long-tailed macaques in Thailand's Ao Phang-Nga National Park bear a striking resemblance to those found in some of the earliest archaeological sites in East Africa, according to researchers at the Max Planck Institute for Evolutionary Anthropology.

The monkeys use rudimentary stone tools, like a hammer and anvil, to crack open nuts. In the process, shards of stone flake off and are left behind. Although the monkeys haven't been observed using them, the shards are similar in size and shape to those unearthed from early human settlements.

"The ability to intentionally make sharp stone flakes is seen as a crucial point in the evolution of hominins, and understanding how and when this occurred is a huge question that is typically investigated through the study of past artefacts and fossils. Our study shows that stone tool production is not unique to humans and our ancestors," said lead researcher Dr Tomos Proffitt. "The fact that these macaques use stone tools to process nuts is not surprising, as they also use tools to gain access to various shellfish as well. What is interesting is that, in doing so, they accidentally produce a substantial archaeological record of their own that is partly indistinguishable from some hominin artefacts."

The discovery offers new insights into how early humans may have began making stone tools and suggests that the practice could have been linked to a similar nut-cracking behaviour.

"Cracking nuts using stone hammers and anvils, similar to what some primates do today, has been suggested as a possible precursor to intentional stone tool production. This study opens the door to being able to identify such an archaeological signature," said Dr Lydia Luncz, of the Max Planck Institute for Evolutionary Anthropology.

Tool use in long-tailed macaques today may shed light on the skill's development in our ancient ancestors

PRIMER

IPCC CLIMATE REPORT

A liveable future can be secured for all if we act now, scientists say

Can humanity tackle climate change or are we all doomed? That's the big question at the heart of a new analysis by the Intergovernmental Panel on Climate Change (IPCC), published on 20 March after a week of discussions with key world climate experts. In short, this report is a big deal. But consisting of 36 jargon-stuffed pages, it's also not an easy read. Fortunately, we've pulled out everything that you need to know.

WHAT IS THIS NEW REPORT?

The new report is the fourth and final section of the sixth assessment report (AR6). The previous three sections of the AR6 were published in August 2021, February 2022 and April 2022. This one is called the Synthesis Report and is a summary of the findings of the three earlier sections and represents the IPCC's most up-to-date thinking on how to best tackle climate change.

WHAT IS THE IPCC?

The IPCC is the United Nations body tasked with assessing the science related to climate change. It was set up in 1988 by the World Meteorological Organization and the United Nations Environment Programme with the aim of providing governments with accurate science that they could base their climate policies around. The IPCC is currently made up of 195 member countries.

It does not conduct its own research. Instead, global experts volunteer their time to assess the thousands of scientific papers published each year, to produce a summary of the current picture regarding climate change and its future risks.

WHAT DOES THE NEW REPORT SAY ABOUT THE CURRENT SITUATION?

It states that, as of 2020, human activity – largely the emission of greenhouse gases – led to a global surface temperature rise of 1.1°C above pre-industrial levels. This is edging ever closer to the 1.5°C limit suggested by the IPCC in 2018 and is chiefly due to the use of unsustainable energy sources, land-use change and patterns of consumption.

This rise in temperature has already resulted in widespread changes in the Earth's atmosphere, weather systems, oceans and biosphere. The last decade has been warmer than any period for around 125,000 years, concentrations of carbon dioxide in the atmosphere are at their highest for at least two million years and summer Arctic ice coverage is lower than any time in the last 1,000 years.

Also, sea levels are rising faster than in any previous century for 3,000 years, oceans are warming faster than any time since the last ice age and ocean acidification is at its highest for 26,000 years.

"Mainstreaming effective and equitable climate action will not only reduce losses and damages for nature and people, it will also provide wider benefits," said IPCC chairperson Hoesung Lee. "This Synthesis Report underscores the urgency of taking more ambitious action and shows that, if we act now, we can still secure a liveable, sustainable future for all."

The report states that each increment of warming will make the challenge progressively more difficult to overcome, with vulnerable regions suffering the brunt of the damage.

"Climate justice is crucial because those who have contributed least to climate change are being disproportionately affected," said report author Aditi Mukherji, director of climate adaptation and mitigation impact area platform at the International Water Management Institute. "Almost half of the world's population lives in regions that are highly vulnerable to climate change. In the last decade, deaths from floods, droughts and storms were 15 times higher in highly vulnerable regions."

ARE WE ALL DOOMED?

Not yet. Although the report does state that the pace and scale of current measures is simply not enough to mitigate the cascading

Anti-coal activists at the Neurath coal-fired power plant in Germany

GETTY IMAGES

effects of climate change, it makes it clear that there is still a chance we can limit temperature rises to 1.5°C if world governments act now.

Key measures that need to be put in place are: rapidly shifting away from our reliance on coal-fired power stations and fossil fuels – the number one driver of climate change; investing heavily in clean, renewable energy; increasing the use of public transport and electrical vehicles; and halting deforestation.

As well as helping to mitigate the effects of climate change, making these suggested changes could also provide wider benefits to society, the report says. For example, if a greater number of people walk, cycle and use public transport rather than their cars, then health and air quality will improve. The economic benefits resulting in increased health due to air quality improvements alone would be equal to, or even larger, than the costs of reducing the emissions, the experts explain.

Changing our dietary habits and food production methods could also play an important role. We can help the climate if we eat more plants and less meat, reduce our food waste and improve agricultural practices.

"Transformational changes are more likely to succeed where there is trust, where everyone works together to prioritise risk reduction, and where benefits and burdens are shared equitably," said Lee.

"We live in a diverse world in which everyone has different responsibilities and different opportunities to bring about change. Some can do a lot, while others will need support to help them manage the change."

WHEN WILL THE NEXT IPCC REPORT BE PUBLISHED?

The next report, the AR7, isn't on cards until around 2030 – by this time we should have a better idea of exactly how bleak, or not, the picture is.

by **JASON GOODYER**
Jason is the commissioning editor at BBC Science Focus.

SPACE

REVEALED: THE SPACESUIT ASTRONAUTS WILL WEAR FOR THE NEXT MOONWALK

NASA has teamed up with private company Axiom Space to design its next-generation suits

When astronauts return to the Moon for the first time in more than 50 years as part of NASA's Artemis missions, this is the spacesuit they will be wearing. Named the Axiom Extravehicular Mobility Unit, or AxEMU, the suit was designed by private company Axiom Space. It was unveiled to the public as part of the Moon 2 Mars Festival at the Johnson Space Center in Houston, Texas, on 15 March.

"Our expert team is ready to provide NASA the next-generation spacesuit," said Mark Greeley, the Extravehicular Activity (EVA) program manager at Axiom Space.

"We carefully considered years of lessons learned by NASA and used that experience to build a spacesuit for the Moon and for our future Axiom Space customers."

The prototype suit on show was fitted with a dark cover in order to conceal the top secret elements of its design. But like all previous spacesuits, AxEMU will be white in order to reflect heat to protect astronauts from the high temperatures they will be exposed to on their mission.

Artemis III is scheduled to land near the lunar south pole in 2025, where the next man and first woman will set foot on the Moon.

AXIOM SPACE X3, GETTY IMAGES

1. The streamlined spacesuit was put through its paces at the Johnson Space Center by NASA's chief engineer Jim Stein.

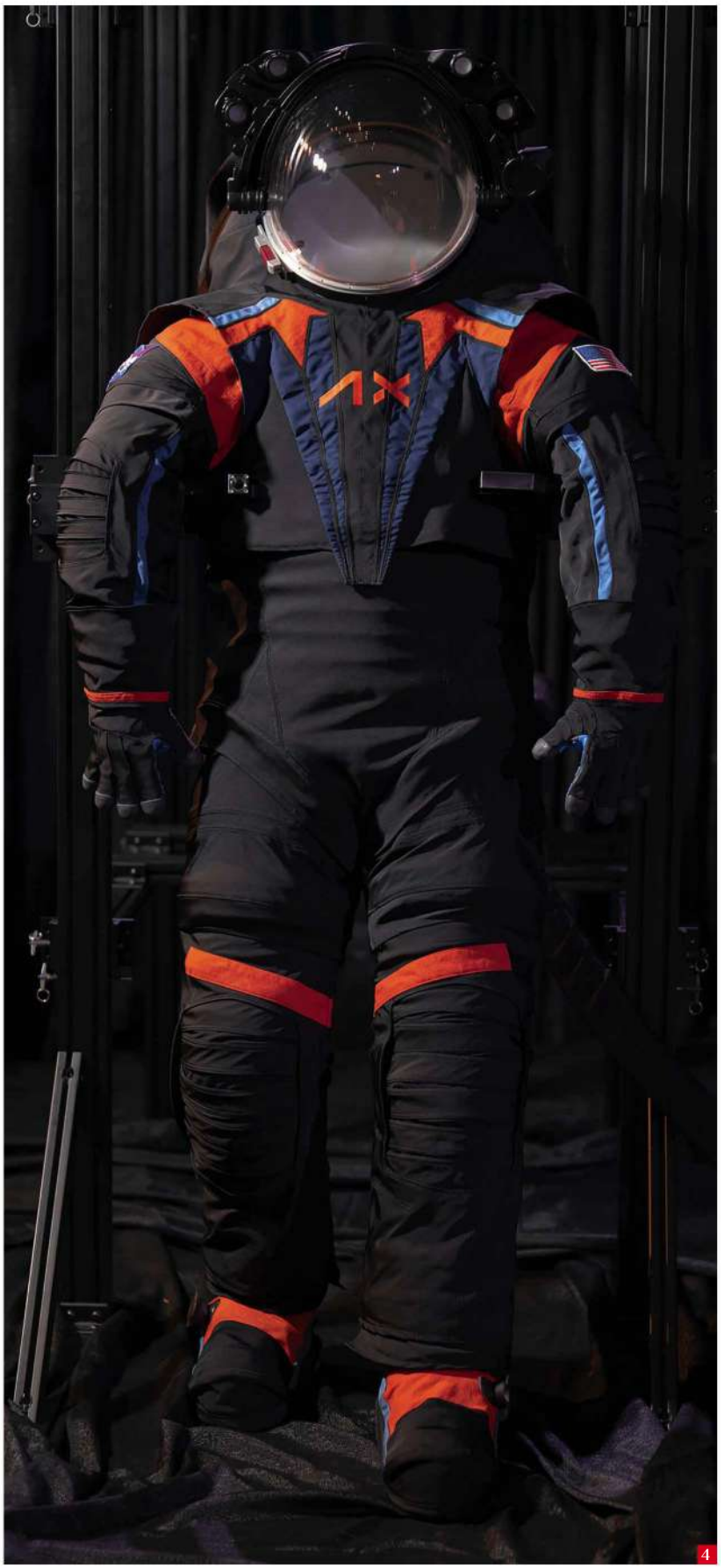
2. This close-up shot of the suit's gloves shows how it was designed with maximum manoeuvrability and agility in mind.

3. The suit features a combination of innovative soft and hard joints to give the astronauts a wide range of motion when they are walking on the lunar surface.

4. AxEMU is designed to fit a broad range of different body shapes and sizes. It can be adjusted so that it is comfortable and non-restricting to wear for 90 per cent of the US population.

2

3



4

THE FUTURE'S BRIGHT...

As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From potato-based concrete to filters that remove forever chemicals, here you'll find many reasons to feel hopeful for our future...

FUTURE VACCINES COULD BE DELIVERED IN A PUFF OF AIR

Not keen on needles? Here's an invention that will pique your interest. Engineers at the University of Texas at Dallas have designed a system that could deliver drugs into the body by puffing them through the skin. Known as the 'MOF-Jet', the device works by encasing drugs in structures known as metal-organic frameworks, or MOFs, and shooting them into the body in puffs of air. Delivering drugs in this way causes no more pain than being hit with a child's toy foam bullet, the researchers say. They are currently using MOF-Jet to deliver chemotherapeutics as a treatment for skin cancer, and plan to extend its use to other drugs in the future.

YEARS TO GO

25

COSMIC CONCRETE MADE OF POTATOES MAY HELP US TO BUILD HOMES ON MARS

Scientists at the University of Manchester have created a new compound out of extraterrestrial dust, salt and potato starch that could be used as a building material by Martian settlers. Dubbed 'StarCrete', the material was made by blending imitation Martian soil, potato starch and salt together in a manner similar to how concrete is mixed on Earth. The potato starch, which would be surplus from food production on Mars, acts as a binding agent to bring the materials together. The resulting mixture has a compressive strength more than twice that of conventional concrete. Despite its cosmic name, StarCrete could also be used as a greener building material down here on Earth, the researchers say.

20

3D-PRINTED FOOD THAT TAKES THE CAKE

What's for dinner tonight? Soon it could be a piece of 3D-printed, laser-cooked cake. Researchers at Columbia University School of Engineering have created a device that can construct a seven-ingredient cheesecake using food inks and then cook it to perfection using a laser. Their creation contained banana, jam, peanut butter and Nutella. Tasty. The technology could one day be used to create personalised meals for everyone from professional athletes to patients with dietary conditions, or it could be useful for those who are simply short on time.

FILTER ZAPS FOREVER CHEMICALS FROM DRINKING WATER

Forever chemicals, or per- and polyfluoroalkyl substances (PFAS), are a group of substances used to make products non-stick or stain-resistant. There are more than 4,700 PFAS in use, and past research has linked them to a wide range of health problems, including cardiovascular disease, developmental delays and even cancer. Now, engineers at the University of British Columbia have produced a filter that can remove 99 per cent of PFAS from drinking water. The filter consists of a unique absorbing material that traps PFAS as they flow through it. These are then destroyed by being zapped with light and electricity. They are preparing to pilot test the filter in locations across British Columbia in the coming months.

10

MIND-CONTROLLED ROBOTS

Researchers at the University of Technology Sydney have developed a biosensor that allows users to operate robots or other devices purely through thought. The device consists of hexagon-patterned sensors that are placed on the back of the user's scalp and an augmented reality lens that displays a bank of flickering white squares. When the user concentrates on a particular square, the sensor picks up brainwaves generated by their visual cortex which can then be translated into movement commands for a robot or other device. Initial tests found that users were able to control the movements of a robot dog with 94 per cent accuracy.

09

3D-PRINTED AIR POLLUTION SENSOR CAN MEASURE AIR QUALITY ON THE GO

The World Health Organization estimates that poor air quality leads to more than four million premature deaths around the world every year. In an effort to help combat this, researchers at MIT have produced a mobile air pollution detector that can track air quality cheaply and quickly. Named Flatburn, the sensor can be 3D-printed or assembled from cheap, readily available parts. It can measure the levels of pollutants, such as concentrations of fine particulate matter and nitrogen dioxide. The construction instructions have been released open-source and the team hopes that Flatburn will be used by individuals or community groups to highlight areas with poor air quality.

JEREMIAH GASSENSMITH, GETTY IMAGES X2, MIT X2, JONATHAN BLUTINGER/COLUMBIA ENGINEERING, ALED ROBERTS

COMMENT

YES, EVERYTHING IN PHYSICS IS COMPLETELY MADE UP. THAT'S THE WHOLE POINT

A physicist's job is to constantly create equations that keep up with our observations of physical phenomena

Researching a cosmic mystery like dark matter has its downsides. On the one hand, it's exciting to be on the road to what might be a profound scientific discovery. On the other hand, it's hard to convince people it's worth studying something that's invisible, untouchable, and apparently made of something entirely unknown. While the vast majority of physicists find the evidence for dark matter's existence convincing, some continue to examine alternatives, and the views in the press and the public are significantly more divided. The most common response I get when I talk about dark matter is: "isn't this just something physicists made up to make the maths work out?"

The answer to that might surprise you: yes! In fact, everything in physics is made up to make the maths work out.

When I first got into science, what excited me was the prospect of learning some ultimate truth about the Universe. The late Stephen Hawking once described cosmology as an endeavour to "know the mind of God". But while that characterisation is inspiring, in practice, physics isn't built around ultimate truth, but rather the constant production and refinement of mathematical approximations. It's not just because we'll never have perfect precision in our observations. It's that the entire point of physics is to create a model Universe in maths – a set of equations that remain true when we plug in numbers from observations of physical phenomena.

For example, Newton's second law of motion, which says that force = mass x acceleration, is a mathematical model that tells us that if we measure the force exerted on an object, in appropriate units, we should get the same number as the product of the object's mass and the acceleration it experiences when subject to that force.

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

"The entire point of physics is to create a model Universe in maths"

In Einstein's version of gravity, General Relativity, the equations get far more complicated, but the goal is the same. There's always a level of abstraction built in to the effort, because what allows us to make predictions or design new technologies is a set of equations that can be written down and calculated, not a philosophical discussion on the nature of reality.

This level of abstraction is especially apparent in particle physics, because the existence or non-existence of a single particle on a subatomic scale is a rather fuzzy notion. The equations describing the motion of an electron through space don't actually include a particle at all, but rather an abstract mathematical object called a wave function that can spread out and interfere with itself.

Is it ever true, then, to say that an electron is 'real' when it's in motion? If we believe that electrons are real things, have we just made up the wave function to make the maths work out? Absolutely – that was, in fact, the whole point. We couldn't get the equations to work if the electron was a solid, isolated particle, so we made up something that wasn't, and then the numbers started making sense.

It may be that in the future we find some solution that we prefer to a wave function and we abandon that concept altogether. But if we do, it will be because the maths stopped working out: we'll have some experimental or observational result that doesn't add up when we put the data into our current equations.

A scientist's notion of what's really happening is always driven by the maths. Before it was accepted that the Earth orbits the Sun, astronomers used epicycles – little orbital loops – to describe planetary motions in an Earth-centred system. This construction is often used, a little unfairly, as a prime example of "making up something to make the maths work" going wrong.

While it's true that we abandoned epicycles in the 17th Century, it was the maths that made us do it. Newton's equations of universal gravitation and Einstein's General Relativity are not made of stronger stuff than the old equations of epicyclic motion, but they fit the observations better and make predictions easier, so we use them as the basis of our abstract model Universe.

While the way we observe something determines what kind of data points we can use, in the end, everything we do is to make the maths work out. We certainly hope that all this calculating brings us a better description of reality, but the mind of God is best left to the philosophers – we don't have an equation for that.

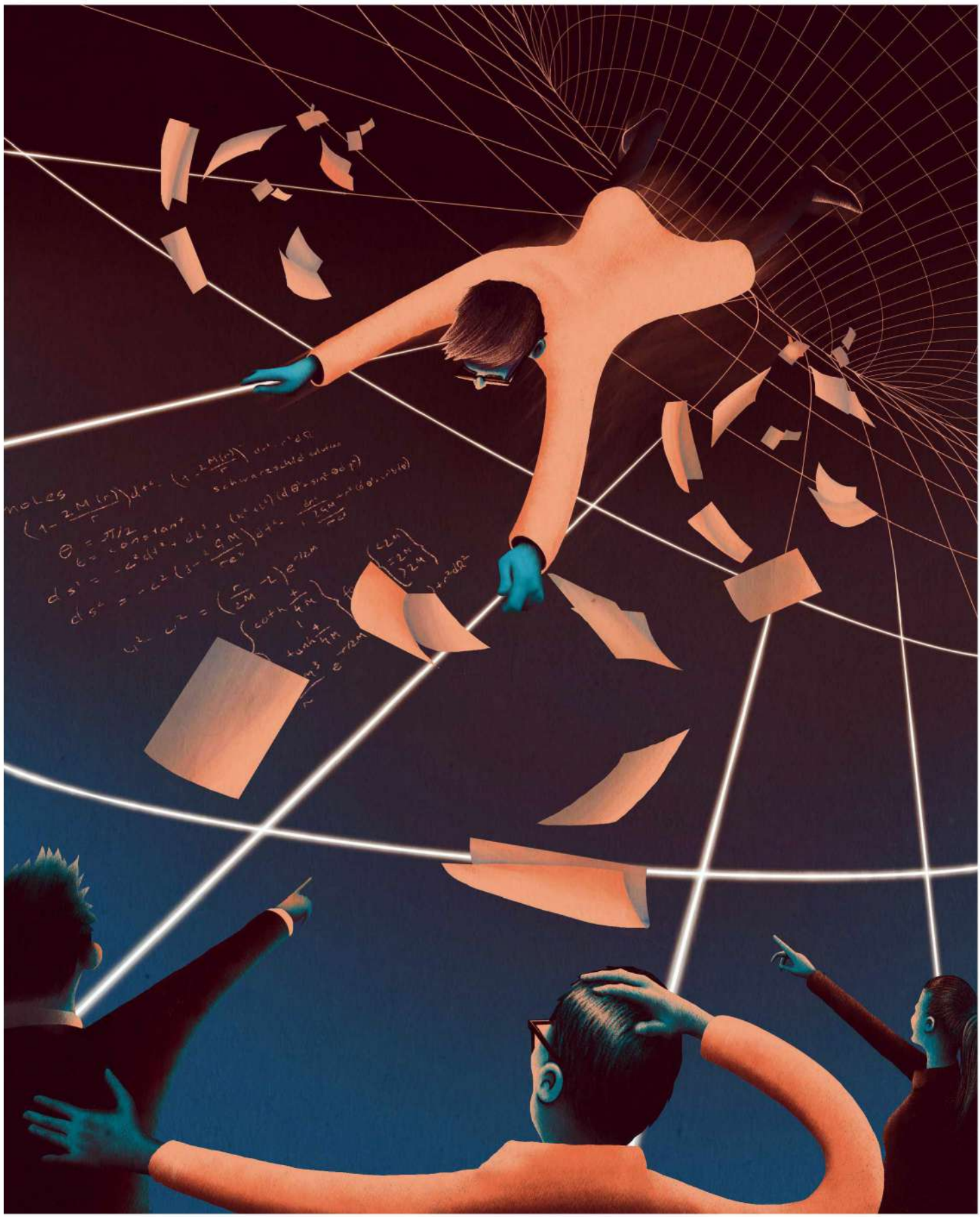
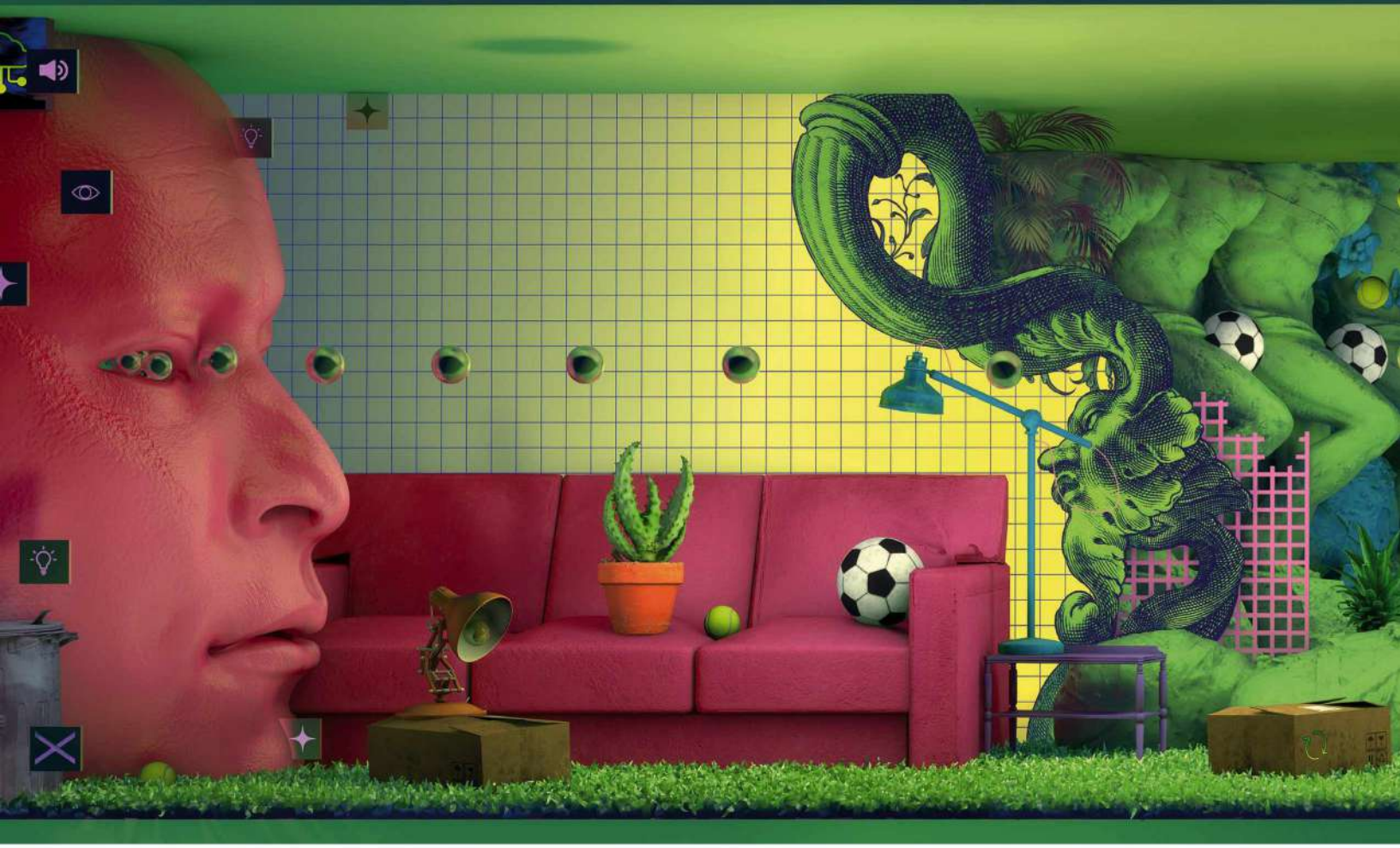


ILLUSTRATION: MATT HOLLAND



COMMENT

DREAMS ARE BIZARRE, SO WHY DO THEY SEEM NORMAL WHEN WE'RE ASLEEP?

Our sleeping brains weave a patchwork out of our memories in complex, baffling ways

Dreams are weird. Utterly impossible events happen in them, then immediately flow into completely different ones, with no obvious rhyme or reason. Contexts, behaviours, individuals… they all shift around randomly during our dreams, with no care for coherent narrative or the laws of physics. It's all very strange. Except it doesn't feel strange while it's happening. We can be dreaming about floating upside down in a cavern of milk, sat alongside someone who is both our mother and co-worker, and our dreaming self will still think, "Yep, this is all to be expected. Typical Tuesday occurrence."

Why is this? Why would our sleeping brain be so blasé about unusual, reality-bending experiences?

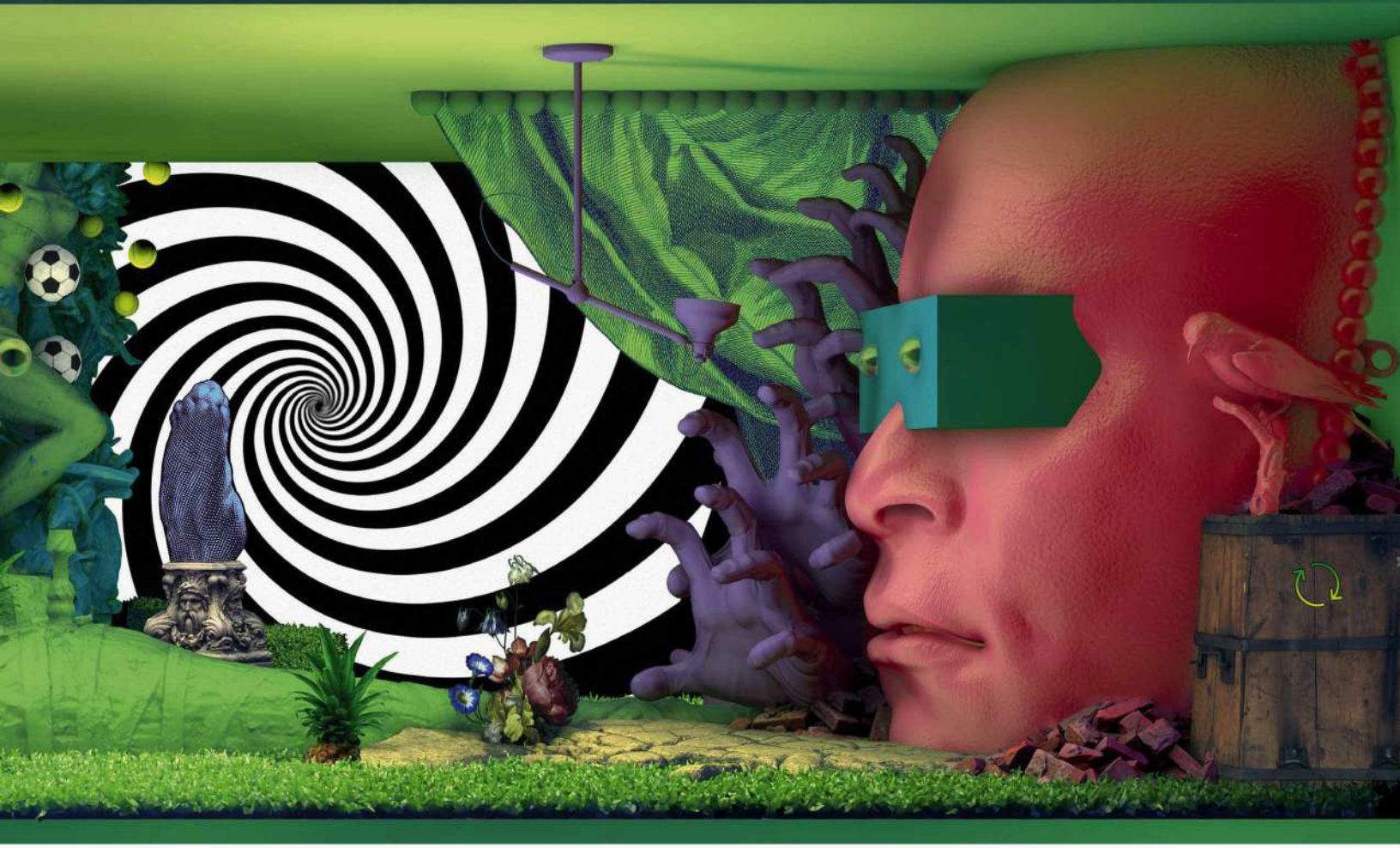
A big part of this is down to the reason we dream in the first place. A growing body of research suggests that dreaming is a vital part of memory consolidation. Our brains don't just create all of the memories we accumulate while we're awake and leave them sat there purposelessly, like most of the photos on the typical smartphone. No, our newly acquired memories need to be effectively integrated into the brain's stores and networks of existing memories that are the basis of our identity, our very minds, and more. This is what memory consolidation is, and a lot of it takes place during our dreams.

Again, this makes a lot of sense, because the time when we're asleep is the time when new memories aren't continuously being created and added to the to-be-consolidated pile. It's like how people working on a road make sure it's closed first, because trying to do their job while cars are still using it would be considerably more difficult.

It's also important to note how memories are stored in the human brain. Biological memories aren't separate, distinct, standalone files of complex information, like the aforementioned photo images in a smartphone. No, it seems that our memories are made up of discrete elements, linked up in unique and complex ways.

For instance, if you're in a long-term relationship, your partner's face will be one of the most familiar things you encounter in your waking life. But if your brain was to create a whole new memory of your partner's face every time you saw them, soon you'd have tens of thousands of memories, all for the exact same thing. This is in no way

ILLUSTRATION: VICTOR SOMA



"Dreams are always made of things with which our brain is already familiar"

efficient, particularly for an organ as demanding as the brain. Instead, it's more that you have one established memory of your partner's face, and when new memories are formed that involve them, those memories are linked to the stored representation of their face.

Elements of memory can represent anything we experience. Sights, sounds, emotions, colours, people, and so on. Combining and connecting these elements in useful ways is what memory consolidation, or dreaming, is for. But when these memory elements are being worked on while we're asleep, they're also being 'activated', like how you need to run power through an electrical circuit to know whether it works. And when a memory is activated, we re-experience it.

But while conscious experiences are consistent with the laws of nature, dreaming experiences are not beholden to such things. Say you are feeling anxious about an upcoming work meeting, then you'll have a load of new memories with an element of anxiety. To better incorporate this new anxiety element, your dreaming brain will link it to other memories that include anxiety. Perhaps you remember being anxious before singing in public or scuba diving for the first time. Your dreaming brain will connect your new anxiety to these existing memories. The end result could be that you end up dreaming about singing underwater. This is an impossible act, but your dreaming brain doesn't care.

Ultimately, everything that happens in a dream is derived from bits of memory, temporarily bound together in complex, baffling ways onto which your brain imposes a sense of 'self', in order to better process things in useful ways.

What this means is, no matter what baffling and impossible things occur in our dreams, they're always made of things with which our brain is already familiar. Because they're memories.

It's as if you came home one day to find your partner has rearranged all your furniture. You might be surprised, but you wouldn't think "What's all this new furniture?" Because you'd recognise it.

This is what our dreaming brain does with our memories. They may be presented in wacky, implausible ways, but the sense of 'this is all familiar' endures. Because, as far as your brain is concerned, everything is familiar.

DR DEAN BURNETT

Neuroscientist Dean explores the nature of dreaming in his latest book Emotional Ignorance *(£14.99, Guardian Faber).*

COMMENT

YOUR CHATBOT WILL SEE YOU NOW: SHOULD YOU TRUST AN AI WITH YOUR MENTAL HEALTH?

Chatbots could provide easier access to therapy, but we don't know whether the risks outweigh the benefits

Years ago, my therapist recommended I read a dog-training book, telling me that "the same principles work for humans". I thanked her, but said it felt too condescending to train my husband like a dog. "No," she laughed, "the book is to help you train yourself." If therapists refer their patients to generalisable frameworks (in this case, even to dogs), then couldn't an AI bot function as a therapist by giving the same advice? The short answer is yes, but we don't know at what risk.

Finding a therapist is hard. The pandemic saw stark increases in depression and anxiety, leading to a global shortage of mental health professionals. Therapy can be expensive, and even for those who can afford it, seeking help requires the effort of reaching out, making time, and scheduling around another person. Enter therapy bots: an alternative that eliminates almost all of the aforementioned issues.

"They might even trust a chatbot more than people, out of fear that a person would judge them"

DR KATE DARLING
(@grok_)
Kate is a research scientist at the MIT Media Lab, studying human-robot interaction. Her book is The New Breed *(£20, Penguin).*

Woebot and other therapy chatbots like Wysa and Youper are rising in popularity. These 24/7 couch friends draw on methods like cognitive behavioural therapy, which has a specific structure and well-established exercises. The premise makes sense, and human-computer interaction research shows that with a chatbot, people can develop a rapport, trust, and a personal relationship. They might even trust it more than people, out of fear that a person would judge them, for example.

But while the existing bots use established therapy frameworks, their effectiveness may depend on how the user engages with them, which is easier for a human professional to guide. To date, there's very little research that indicates whether therapy bots work, whether they're good or bad for people, and also who they're aimed at.

In 2018, Woebot came under fire for unwittingly endorsing child sexual exploitation. That issue was addressed, but it won't be the last. Newer generative AI methods could make a bot's responses feel less canned, but still have the problem that nobody can predict exactly what the bot might say, which is particularly risky in a therapy context. AI-based text systems are notorious for baked-in sexism, racism, and false information.

Even with pre-scripted, rule-based answers, it's easy to cause harm to those seeking mental health advice, many of whom are vulnerable or fragile. While the bots are designed, for example, to recognise suicidal language and refer out to human help, there are many other situations where a bot's answer might be misguided, or taken the wrong way.

Good therapists are skilled at knowing when and how (and how hard) to push someone in a certain direction. They read between the lines, they observe gestures, they notice changes in tone, all of which help inform their responses. They work to strike a difficult balance between meeting their patient where they're at, and also moving them forward. It's such a difficult skill that even human therapists make missteps.

Bad human therapists are undoubtedly harmful. The profession has seen everything from unsafe advice, to therapists scamming their clients out of their life fortunes. But it has also been geared toward preventing harm, with ethics codes, licence requirements, and other safeguards. Entrusting the sensitive data collected in a mental health context to a person is different from entrusting it to a company. Human therapists may make mistakes, but they aren't risky at scale. And the promise of these therapy bots is exactly that: scale.

The big selling point – and it's a compelling one – is increasing access to therapy. Lowering the barrier to mental health services is undoubtedly valuable, but we don't yet know whether the risks are worth the benefits. In the meantime, there are ways to support people without trying to recreate human therapists.

Ironically, a better solution may be simpler technology. In the 1970s, Joseph Weizenbaum created a chatbot named ELIZA that mostly responded to users with simple questions. Traditional journalling, a technique recommended by many therapists, is made more accessible to people through interactive formats like ELIZA. There are also mood-tracking and meditation apps that support people on their mental health journeys.

Some of the therapy bot creators distance themselves from the replacement narrative, claiming that they, too, provide a supplemental tool. But their tool isn't designed to enable therapists to better serve clients, or to be used as an intervention alongside therapy. It's primarily used as an alternative for people who can't or won't get a therapist. Maybe that will turn out okay, but app designers should be honest about what they're doing.

ILLUSTRATION: VALENTIN TKACH

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Laughing gas | Testosterone | Lucky girl syndrome

WARNING
Laughing gas is a psychoactive substance according to UK law. At the time of writing, supply can get you a seven-year prison term, a fine, or both. Information and support for those affected by substance abuse can be found at **bit.ly/drug_support**

REVIEW

LAUGHING GAS: IS IT HARMFUL, AND WHY DO POLITICIANS WANT TO BAN IT?

The last few years have seen a huge increase in the recreational use of laughing gas in the UK

"This is probably the first and only example of a music-hall trick leading to a medical advancement"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

At the end of March, the UK government announced that the possession of nitrous oxide, or laughing gas, will soon become a criminal offence. But how dangerous is it? David Nutt, the Edmund J Safra Professor of Neuropsychopharmacology at Imperial College London, explains the drug's effects, its current legal status and the associated risks of using it.

WHAT IS LAUGHING GAS?

Nitrous oxide, or laughing gas, is a Great British invention. It was discovered in 1780 by Joseph Priestley in Birmingham, and then tried by president of the Royal Society Sir Humphry Davy. After inhaling it from a silk bag, Davy reported he "lost touch with all external things", entering a realm of pure thought which he described as a "world of newly connected and newly modified ideas". He was so taken by this effect of the gas that he even started a new branch of science based on these insights that he called 'chemical philosophy'.

The recreational aspects of laughing gas then dominated its use for the next 50 years. Posh people hosted laughing gas parties and demonstrations were given in music halls where customers could volunteer to try it. Some of them fell off the stage, but reported they did not feel pain. This observation led to nitrous oxide being used as an anaesthetic. Now, 170 years later, it still is, especially for childbirth and re-setting dislocated joints and broken bones. This is probably the first and only example of a music-hall trick leading to a medical advancement.

WHY IS IT BACK IN THE NEWS?

In the past 20 years, recreational use of nitrous oxide has again become popular. There seem to be several reasons for this. One is that it is now readily available in small metal canisters called whippits that are used in the catering industry to froth creams. The user opens the whippit, fills a regular party balloon with the escaping gas, and then inhales the gas from the balloon.

A lot of the antipathy towards nitrous oxide in recent years is because users often throw away the used whippits, littering streets and parks where they look unsightly and people can slip over on them.

Its upsurge in popularity has led to repeated calls to ban its sale. The latest is being led by Home Secretary Suella Braverman who has branded recreational use of the drug "unacceptable". At the time of writing, it is illegal to sell nitrous oxide to anyone under the age of 18. It is also illegal to sell it (or 'deal it') for recreational purposes, but personal possession is not currently against the law. This may soon change, however.

HOW HARMFUL IS NITROUS OXIDE?

All experts agree that nitrous oxide scores low on ratings of risk and harm and it rarely causes death. But it isn't completely harmless, especially if it's used excessively. Aside from short-lived unwanted effects such as nausea, confusion and accidents, which are more common when it's taken with other substances, the biggest risk is that it can cause nerve damage because it depletes levels of vitamin B12, which helps nerves to work properly. The first signs of this are persistent numbness →

ALAMY X2

BELOW Nitrous oxide is a useful anaesthetic, and is often offered as 'gas and air' during childbirth to reduce the intensity of labour pains

ABOVE Used laughing gas 'whippits' are now a common sight on our streets

→ or tingling around the tongue or lips, feet and fingers that can then progress to pain and paralysis of the nerves or even the spinal cord. Note that vegans often have low B12 levels so are more at more risk.

The vast majority, around 70 to 80 per cent, of people who use nitrous oxide do so fewer than 10 times a year and use about five balloons. This moderate consumption reduces the risk of harm and gives the body time to replenish vitamin stores.

But some heavy users can damage their nerves so severely that they end up in wheelchairs. This wasn't very common in the days when people used balloons filled from whippits. But recently, as the police have clamped down on the sale of these, users have moved to big, industrial cylinders.

These contain large amounts of nitrous oxide – equivalent to hundreds of whippits – so it's easier to use much more gas in any one session. Also, when someone is inhaling nitrous oxide, they aren't taking in air, so too much continuous gas intake could starve the brain of oxygen in the same way as if they were suffocating.

Dependence on nitrous oxide as such has not been seen, but a small number of people have reported compulsive use and so are at a greater risk of nerve damage and other complications of vitamin B12 deficiency such as heart problems and anaemia.

Inhaling directly from a whippit can also be dangerous as it can freeze the user's mouth. A final important safety concern is for users who drive while under the influence of nitrous oxide – this is illegal and very dangerous.

by **PROF DAVID NUTT**
David is a psychiatrist, the Edmund J Safra Professor of Neuropsychopharmacology in Imperial College London, and chair of ***drugscience.org.uk***

ANALYSIS

TESTOSTERONE: IS IT A MENOPAUSE WONDER DRUG?

The number of women receiving prescriptions for the hormone has increased 10-fold in less than a decade

According to data analysed by *The Pharmaceutical Journal*, testosterone prescribing for women in the UK has increased 10-fold between 2015 and 2023. Behind this is a trend for testosterone being portrayed as a quick fix for complex issues faced by women going through perimenopause, the time when a woman's body prepares to make the natural transition to menopause. But there's no clinical evidence to support this and testosterone in women is currently unlicensed in the UK.

Premenopausal women produce testosterone naturally in the ovaries. It is required for the development and maintenance of female sexual organs and sexual behaviour. It is also important for muscle and bone strength, and growth of normal body hair. And it may have favourable effects on mood, wellbeing and energy in women.

Testosterone levels appear to decrease as you get older, not just during perimenopause. Although for those who go through induced menopause, after having their ovaries surgically removed, testosterone levels can fall suddenly by up to 50 per cent.

But there is no level of testosterone below which a woman can said to be deficient, and a 'testosterone deficiency syndrome' has never been clinically defined.

Testosterone is one of the hormones involved in female sexual desire, and low circulating levels are associated with diminished libido. Research studies indicate that many women reporting loss of libido (clinically defined as Hypoactive Sexual Desire Disorder) benefit from testosterone therapy.

But libido is a complex multifactorial function, not ruled solely by hormones. It involves physical, psychological and practical aspects. Taking testosterone will alter the biological state, but is commonly insufficient on its own – as typically there are many other issues involved, such as low self-esteem, relationship problems, time alone without children interrupting, and certain medications.

So why is there a rise in testosterone prescribing? The National Institute for Health and Care Excellence (NICE) and the British Menopause Society both recommend testosterone as a medication for low

GETTY IMAGES, SHUTTERSTOCK

"Without adequate evidence, as is the case with testosterone therapy, doctors are left with just opinions and anecdotal user reports"

libido in some women. However, it should be used only when all other treatments, namely oestrogen, have been unsuccessful. So, although there are grounds for the use of testosterone treatment, its use in women is controversial.

Prof Susan Davis, a leading researcher in this field from Monash University, Melbourne, Australia, conducted the most comprehensive analysis to date of all research on testosterone treatment in women. It included 36 trials involving 8,480 women.

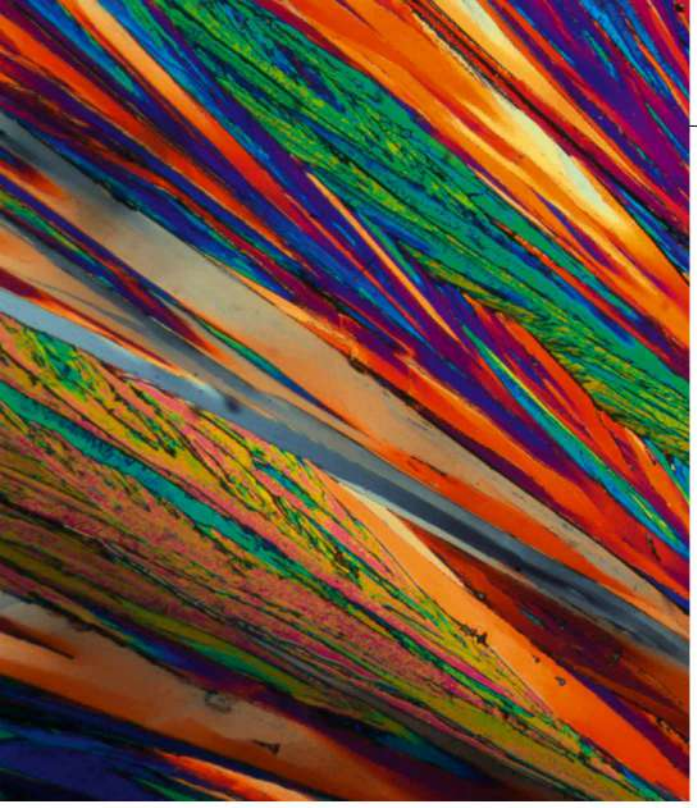
Testosterone in postmenopausal women, compared to a placebo or other hormonal medications such as oestrogen, did significantly increase frequency of sex as well as sexual desire, pleasure, arousal, responsiveness and self-image. However, the review found no benefits for cognitive measure, bone density, body composition, muscle strength or psychological wellbeing.

It did also show side effects, including acne and increased hair growth. And it is clear more research is needed before definitive answers can be given on the efficacy and dangers of testosterone treatment. NICE recognises this and has requested the National Institute of Health Research (NIHR) to scope out the research that needs to be done. To help this process, the NIHR is collaborating with the British Menopause Society to understand the topic further and plan clinical trials.

So, testosterone treatment in women is a complex area that needs more research. But social media is now exerting a strong influence. It is promoting testosterone to solve many symptoms and issues for women going through perimenopause – such as low libido, but also low mood, tiredness and poor concentration. This includes what the media calls the 'Davina McCall effect' thanks to a video on Instagram of Davina applying her testosterone gel and talking about its benefits. As she is the presenter of recent popular TV shows about menopause, this is fuelling the sudden demand for prescribed testosterone.

ABOVE While testosterone can help with sexual desire and arousal in postmenopausal women, it doesn't appear to offer any cognitive or psychological benefit

This is a problem, as medicine is evidence-based. And without adequate evidence, as is the case with testosterone therapy, doctors are left with just opinions and anecdotal user reports, which leaves women open to receiving a treatment that's potentially dangerous. Anecdotal accounts from celebrities, or anyone, →



ABOVE Crystals of testosterone, as viewed using polarised light microscopy

→ should not be used to inform women on the correct medical treatment for them.

A drug should be prescribed following a shared decision-making process between doctor and patient. The doctor's role is to provide all the necessary evidence to inform the patient and help to make the right decision for them.

Personal opinions on social media shouldn't be part of this. Let's not forget that testosterone is a regulated drug, not something you can just pick up from the supermarket. That means robust evidence of its efficacy is needed.

This whole issue taps into a wider problem – that expectancy and acceptance surrounding non-evidence-based treatment for women's medical conditions is on the rise. But women have the right to evidence-based healthcare.

The use of anecdotes rather than evidence devalues the importance of scientific data in women's health and is at the core of a growing problem. Large pharmaceutical companies may see that women are driving sales of hormone replacement therapy based on anecdotes and social media alone, which means they have no incentive to run the trials that can prove or disprove the efficacy of medication. Consequently, this puts women's health research and future treatment options at significant risk.

by **DR MICHELLE GRIFFIN**

Michelle is director of MFG Health Consulting. She has nearly 20 years of experience in women's health as an obstetrician and gynaecologist in the NHS, Public Health England and the World Health Organization.

COMMENT

POSITIVE AFFIRMATIONS: CAN THEY IMPROVE YOUR LIFE?

Could #LuckyGirlSyndrome, the latest TikTok craze, do more harm than good?

On TikTok, a craze has run wild under the hashtag #LuckyGirlSyndrome, which at the time of writing has over 600 million views. You can take your pick of popular female TikTokers who purport to explain the concept.

Their shared claim is that once they started repeating mantras or 'affirmations' on a regular basis, such as "I genuinely believe that the best things just happen to me" or "Things are always working out for me no matter how it looks at any given point in time", they created their own luck and amazingly good things started happening.

For instance, one typical advocate of the method, who credits the technique with her launch of a successful business, a new friendship circle and much more, explains that "if you revert back to the mantra of 'I'm so lucky, everything is always happening for me', and that really gets a feeling of luck and excitement going within you, that changes your frequency right there ... and it will totally magnetise different things into your life."

The craze is imbued with a kind of pseudoscience that goes by different names, such as the 'law of assumption', 'law of attraction' and 'manifesting' – essentially, that by acting as if good things always happen to you, they will. There are echoes of 'cosmic ordering' (once championed by TV star Noel Edmonds – remember him?), which is the New Age belief that if you write down a wishlist of things you want to happen, they will.

From a scientific perspective, such dramatic notions are, on the face of it, nonsense. Critics have also rightly pointed out the potential for harm in spreading the idea that many people facing difficulties in life are to blame for not being positive enough, thus taking the focus off the systemic and societal injustices – or old-fashioned bad luck – that are truly responsible for their plight.

And yet, so many TikTokers swear by the positive affirmation method. This is no doubt because of confirmation bias – after adopting the Lucky Girl philosophy, they attribute to it any good thing that consequently happens. And they explain away bad outcomes as temporary blips.

SCIENCE PHOTO LIBRARY, GETTY IMAGES

"After adopting the Lucky Girl philosophy, TikTokers attribute to it any good thing that consequently happens"

ABOVE It doesn't matter how many fingers and toes you cross, simply thinking yourself lucky will not lead to positive change

What other aspects of psychology are at play? Simply wishing things to happen might be ineffectual, but many of the advocates for #LuckyGirlSyndrome talk in terms of the power of positive mindsets. Is there any truth to the idea that uttering self-affirming mantras can cultivate a positive mentality that really does have knock-on benefits in life?

Here, the psychological science becomes a little more nuanced. On the one hand, the research literature suggests that telling yourself you are lucky and visualising your goals – but without doing anything active to achieve those goals – is, if anything, likely to backfire. There is an evidence-based technique known as 'mental contrasting' that shows we are actually much more likely to achieve our goals if we spend time considering what might go wrong, and what hurdles lie ahead. The reason this is beneficial is that it helps us anticipate future difficulties and find solutions.

Yet on the other hand, there is a wealth of research showing the benefits of being generally optimistic in life. On average, optimists tend to be happier, live longer and are healthier. This is thought to be because having positive expectations naturally lowers worry and stress.

Optimists are also encouraged by their positive outlook to invest time and effort into their aims and interests. There is even a legitimate, evidence-based exercise, known as the 'best possible self' intervention, that involves spending time imagining yourself in the future with all your dreams and desires fulfilled, which has been shown to increase people's optimism.

Note that this line of research does not back up the simplistic #LuckyGirlSyndrome notion that saying you're lucky makes you lucky, but it does imply there could be benefits to being hopeful and motivated (especially if you follow through with hard work).

There is also a serious line of research into the beneficial effects of positive self-affirmations. However, in the psychological literature, these are not hollow mantras about being lucky in life. Rather they are all about a person vocalising and renewing their commitment to what they value – for instance, being independent, being a member of a particular social group or organisation (such as a school or university), or being humble or being an athlete. Studies show that affirming one's values in this way can help protect against unjust stigma and stereotyping. **SF**

by **DR CHRISTIAN JARRETT**

Christian is a psychologist and writer. He is the deputy editor of Psyche, *the sister magazine to* Aeon. *His latest book is* Be Who You Want *(£14.99, Robinson).*

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

REVIEW
BEELINE VELO 2
Can this bike GPS stop staff writer Alex getting lost? **p44**

FIVE OF THE BEST
MASSAGE GUNS
We try out the latest must-have tools for fitness fans **p46**

NEW TECH
IDEAS WE LIKE
Our pick of this month's greatest new gadgets **p48**

A tasty pizza in less than two minutes? Mamma mia! p48

The massage gun market was valued at £285m in 2023 (Source: Maximize Market Research)

87% The percentage of people in a study who fell asleep faster when using a massage gun (Source: Therabody)

39% The percentage of global sales of massage guns that are coming from North America (Source: TechNavio)

REVIEW

Beeline Velo 2: a cycling computer for easy navigation

Alex Hughes goes for a spin with Beeline Velo 2, a simple and streamlined bike GPS

Unlike the black cab drivers of London, who know every street, turn and dead-end in their own city, I have the memory of a goldfish when it comes to navigation, second-guessing how on Earth to get around the city I live in.

To remedy this, I have utilised the tried-and-tested method of strapping my smartphone to my bike and booting up a map app. Sure, it works, but not only am I scared for the safety of the device, it is also surprisingly unintuitive, sending me up huge hills, or down roads that are simply not made for bikes.

While there are plenty of dedicated sat-navs for bikes, one that particularly caught my eye was the Beeline Velo, which costs £99.99. Simple, easy-to-use and supposedly packed with smart features, could this bike tracker be the tool that would finally make me a successful city navigator?

In 'route tracker' mode, you follow a traditional map that shows your turnings

DESIGN AND FEATURES

The Beeline Velo 2 is simple in design and structure. The device itself features a rounded screen similar to a smartwatch, with four switches on the back. This then clicks into the handlebar mount with a simple twist, and it stays secure until you twist it back out. You then attach this to your bike with the included rubber bands. The bands are sturdy and I was never concerned about the device falling off, but it isn't exactly the most premium method out there, when similar devices will attach to your bike using some sort of a grip or screw method.

Once the device is turned on, you can set a route via the app. The route will then appear on the Beeline. This can be either as a road map, highlighting the road you're on and when to turn, or simply a compass pointing you in the general direction of your destination for the more adventurous. You can apply pressure on the top, bottom, left and right of the Beeline to access different settings and navigate through the device. Via these buttons you can see your device's battery life, stats about your journey, arrival times, average speeds and more.

USING THE DEVICE

Once the device was set up (which did not take long at all), I used the app to set my first destination. I rode a fairly simple three-kilometre journey, heading to a nearby shop that I didn't know the route to.

There is an easy 'plan ride' option on the app. Through this, you are given a map that feels similar to Google or Apple Maps. Enter your end destination and the route pops up on the Beeline.

I first used the 'route tracker' option. On the device, this showed a more traditional map with the road I was travelling on and where my turnings were. This was the more useful mode, offering exact turns, distances and a view of the upcoming route.

Helpfully, the Velo makes a beep when you approach turnings to gently remind you when you need to change roads. But

The device attaches to the mount, which then fixes to your handlebars with rubber bands

"WHETHER WITHIN THE CITY CENTRE OR ON THE OUTSKIRTS, I WAS GIVEN DIRECT AND EASY ROUTES"

when I did make wrong turns the tracker could take a long time to recalibrate, especially if I made a few turns before it had decided my new route.

Thankfully, I was able to stick to the route the majority of the time. However, when I did go wrong, I got to use the 'compass mode', which I was a big fan of. In this mode, the device shows a spinning arrow pointing you to your end destination. This allows you to take any road without losing track of where your end destination is.

Whichever navigation mode you use, the map is relying on your smartphone to process the route. For the most part, this is absolutely fine, but if you lose signal and go off the designated route, the Beeline won't be able to recalibrate. This left me a bit stuck when I once hit a route with a deadend of roadworks in an area with no signal.

On most of the rides I took, whether within the city centre or on the outskirts, I was given direct and easy routes without any major problems, even when I took a slight detour and needed to wait for a recalibration.

One of the Beeline's more interesting features is its rating system. When you take a route, you can rate a section of it as either good or bad. These ratings are then fed into the company's mapping algorithm which, in theory, will give better routes for users as time goes on.

For instance, when I took a ride into work, I came across a tight road up a hill which was not logical for bikes. After down-rating it, the route had been changed next time I took it.

While I mostly used the device for navigation, I also found it handy for quickly checking stats, such as arrival times, how long I had been riding and my average distances.

VERDICT

The Beeline Velo 2 ticks a lot of boxes. It is fairly affordable, easy-to-use, non-invasive when you're riding and packed with plenty of features.

Whether I was following the compass or a more direct route on the map, I was consistently happy with its performance, and rarely found myself experiencing any major issues.

While it isn't perfect and its heavy reliance on a smartphone and mobile signal might put off some users, for the average commuter or hobby cyclist, the Beeline Velo 2 is an excellent choice.

RATING

★★★★★

PROS:

- Easy to use and install
- Affordable
- Good battery life
- Useful app

CONS:

- Struggles to recalibrate
- Tricky to use on the go
- Third-party apps don't always work well

THE BEST ALTERNATIVE BIKE TRACKERS

GARMIN EDGE 1040 SOLAR

A pricier alternative, this is for serious cyclists. Its big selling point is that it charges via solar, so if you're cycling in the sunshine, you can go days without needing to charge it. Along with being able to plan routes and show the best directions, it can also display your riding times, speeds and other statistics, and can show you where your weak points were on a route.

£629.99, garmin.com

SIGMA ROX 11.1 EVO

At a similar price to the Beeline Velo 2, the Sigma Rox 11.1 Evo is an affordable yet feature-packed bike tracker. It offers a user-friendly interface and some handy training data. You can put in destinations to be tracked, and it can measure the cadence of your ride, and check your speed and distance. With 150 other functions to track your performance, it's one smart bit of kit.

£169.99, sigmasports.com

GARMIN EDGE 530

While the solar-powered Garmin above is impressive, its price is rather steep. The Garmin Edge 530 is a cheaper alternative. It offers a solid navigation system, but struggles when you go off the planned route. It can also track your speed, altitude, power, heart rate, cadence and calories. One downside is that it's non-touchscreen, so you can't easily scroll along your route.

£259.99, garmin.com

Five of the best massage guns

These tools promise to aid recovery after a workout and count Rihanna and Marcus Rashford among their fans. James Witts picks his faves

Homedics Myti Mini Massage Gun

£119.99, homedics.co.uk

The Homedics Myti is only 14cm high and weighs just 350g, but it packs an impressive 3,000 percussions per minute (ppm) at top speed, which is the peak of its four modes. Its petite size is matched by its petite sound, as this is one quiet gun. It comes with four head attachments: ball, U-shaped, flat, targeted and even heated. The heated flat massage head warms up to 45°C in just 15 seconds and is designed to further stimulate bloodflow within the muscle tissue to accelerate recovery. It's USB-C rechargeable for use on the go, lasts for a maximum of three hours and comes in a svelte protective case. All in all, it's impressive stuff, though we'd like a little more exercise guidance in the instruction booklet and online. Those looking to target larger muscles in a massage session might want something a little bigger.

Hyperice Hypervolt 2

£299, hyperice.com

The Hypervolt 2 is the beefiest gun on test, though it only hits the scales at 0.8kg. It comes with five head attachments – fork, ball, cushion, flat and bullet. It's quiet for a unit housing a 60W motor, and recharges via an 18V charger. On full charge, it lasts for a maximum of three hours. It has a robust, sturdy feel and features three speeds (2,000, 2,350 and 2,700ppm), of which the highest setting packs quite a punch. We spent most of the test period utilising the company's Hypersmart feature. This is a really neat feature where the gun connects to the Hyperice app that contains dozens of workouts, from 'run recovery' to 'all-day desk tension'. Choose your desired workout and the app will control the gun's pressure as it guides you through the respective session. It's an impressive piece of kit, with the only downsides being that hefty price tag and the fact the gun doesn't come with its own case.

Muscle Gun Carbon Go

£169.99, muscleguns.co.uk

The Muscle Gun Carbon Go weighs just 510g and has three modes, peaking at 3,200ppm, and is quiet like its contemporaries. Its ergonomic design is slightly angled, so fits snugly into the palm of your hand. It has four heads – fork, ball, flat and bullet – that do a job, albeit the ball feels akin to a very lightweight squash ball and on the verge of popping at any moment. As is a theme in this test, the device's battery life is a maximum of three hours from USB-C charging. It's another fine miniature offering, though if we're being pernickety, it's the only one here that doesn't have LEDs to indicate which mode you're in. You're given anatomical guidance via a paper manual and app, albeit it's not as clear as the Hyperice offering, and it doesn't deliver workouts via syncing to the app.

Renpho R3 Active

£104.99, renpho.uk

Despite weighing just 680g, the Renpho R3 Active is a powerful beast that's affordable too. We appreciate the detail on their website, especially when it comes to the mooted benefits at the different modes. According to Renpho, at 1,800ppm it wakes up muscles; fascias are released at 2,100ppm; 2,500ppm and you're eliminating lactic acid; you're enjoying deep-tissue massage at 2,900ppm; and 3,200ppm is all about muscle recovery. Of course, the paucity of independent studies means you can't take those figures as read, but it's certainly user-friendly advice. It's portable and comes with a protective case. And that feature list stretches to the attachments, of which there are five: bullet head, flat head, air cushioned head, ball head and fork head. It's also pretty quiet.

Theragun Elite

£375, therabody.com

The Theragun Elite is one of the more premium massage guns currently on the market. It comes with five possible attachments, which are all aimed for different parts of the body, plus five separate speed settings: 1,750, 1,900, 2,100, 2,200 and 2,400ppm. While it was nice to have the choice, we mostly stuck to the lowest speed as this offered more than enough pressure. For those looking to really dig in deep to the muscles, the higher speed options and more pointed heads can really do the trick. The Theragun Elite offers a special handle design which is great for reaching awkward spots on your back. With the triangular handle, you can hold it in a multitude of ways, compared to the stick-style handles seen on other massage guns.

Ideas we like...

Our pick of the month's smartest tech

↓

...the pizza oven goes electric

The pizza oven brand Ooni has established itself in gardens across the UK. However, for those in a rush, or who are quite frankly too lazy to start the fire in the bottom of the oven, Ooni has a solution. The Ooni Volt 12 uses no pellets, fire, or gas. Instead, it's powered by electricity to make a perfect pizza in two minutes. Plus, the Ooni Volt 12 can be used indoors, so your pizza party won't be a washout when the inevitable British weather arrives.

Ooni Volt 12
£799, uk.ooni.com

↓
...surrounded by music
Sonos isn't exactly known as the most adventurous audio brand, offering an array of powerful but plain speakers. Now, it is taking a slightly different route with its Era speakers. Shouting audio out of both sides, these spaceship-styled speakers aim to fill a room with powerful audio all around you. This, paired with Dolby Atmos technology, gives you a truly immersive audio experience. They aren't cheap, mind.

Sonos Era 300
£449, sonos.com

↓
...assistive technology reaches the camera world
Sony is the latest brand to break into the assistive technology space, with its DSC-HX99 RNV camera that allows a visually impaired user take photographs. The viewfinder projects a weak laser image directly onto the user's retina, so they can see what they're photographing in colour. Sony is absorbing some of the costs of these devices, to keep things more affordable for users.

Sony DSC-HX99 RNV
$600 (£490 approx), sony.com

↓
...music quality taken seriously
For those who are happy with their £5 headphones, the FiiO R7 will seem excessive, but for the audiophiles of the world, it will be a new must-have device. FiiO claims the R7 can operate as both a high-resolution audio player and streamer, as well as a dedicated headphone amplifier. Normally, this would require two separate devices, so we'll wait to see how well it can perform.

FiiO R7
£649.99, fiio.com

↓
...sending texts in an emergency
The dreaded no-signal sign on your phone is an experience shared by campers, hikers and hungover festival-goers. Motorola's solution is the Defy Satellite Link, a device that enables almost any smartphone to send and receive text messages, even in places lacking signal. You can share your location, send out an SOS and have a two-way conversation using the device.

Motorola Defy Satellite Link
£149.99, motorolarugged.com

IDEAS WE DON'T LIKE...

...YET ANOTHER SMART GLASSES ATTEMPT
Ten years ago, Google released the Google Glass, a pair of smart glasses that were set to change the world. They did not. Since then, countless brands have tried the same, all falling short of the mainstream. Now Xiaomi is giving it a go. The prototype Xiaomi Wireless Glasses aren't exactly inconspicuous, with two large cameras and a bulky frame. Through augmented reality, you can watch TikTok via the glasses, try out furniture in a room and generally interact with an altered version of your reality. It's fun, but nothing we haven't seen countless times before.

mi.com

...A NEW WAY TO LOOK AT VINYL
Like dumping caviar and gold flakes on food, slapping a 'limited edition' label on something is a surefire way to ramp up the price. At a whopping £3,394, we can't help but feel that's what is happening here with the Miniot Black Wheel. It's a record player that flips on its side, lifting your vinyl of choice into the air. From there, a set of light-up buttons gives you control over your music. While it is certainly unique and packed with high-end audio technology, it will leave you with a very empty wallet.

Miniot Black Wheel
£3,394, miniot.com

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Venus
Testosterone
Physics
UNLOCKING THE POTENTIAL OF LUCID DREAMS
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JAMES WEBB SPACE TELESCOPE THE UNIVERSE SEEN ANEW
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TIRED ALL THE TIME?

the
Avocado
diet

3 RULES BEHIND EVERY DIET THAT WORKS

We're fed up with navigating all the tips and advice online telling us how to lose weight, so we asked an obesity expert to reveal whether anything actually works for weight loss

by **PROF GILES YEO**

Many of us would like to shed a few kilos, and keep them off. This has never been more relevant, as three years of pandemic living has resulted in some of us putting on unwanted weight. But if you head online for some advice, prepare to be disappointed. Doctors, scientists and influencers seem to be locked in a tussle over what exactly works when it comes to shedding fat. There's the like of diet expert Prof Tim Spector, who set TikTok 'influencers' into a sweaty flurry over his soundbite on the *Diary Of A CEO* podcast when he said "exercise doesn't work". To clarify, it is of course possible to lose weight through exercise. After all, Tour de France cyclists eat around 5,000 calories a day and still lose weight during the three-week race. The problem is, most of us mere mortals don't exercise anywhere near enough for this to be effective. Others, like myself, have argued that counting calories has its limitations, and we shouldn't slavishly follow the calorie counts listed on food packaging.

Still more people quibble about which diet (of the hundreds out there) will actually get you looking lean, and permanently so. I'm not in the business of endorsing any one of the many different dietary approaches that rear their heads online, because – whatever anyone tells you – there is no magical 'one-size-fits-all' solution. But do any diets actually work? The answer is, surprisingly, yes, although perhaps not for the reason that is often being marketed. In one respect, the truth about diets is a simple one: for a diet to work, there has to be a calorie deficit. If we forensically examine ALL the diets that show some evidence of working, the vast majority all share one (or more) of these three characteristics:

1. **They explicitly restrict calories**
2. **They are high in protein**
3. **They are high in fibre**

Let's look at these in a bit more detail. →

ILLUSTRATION: GRACE RUSSELL

1 CALORIE RESTRICTION

Not all calories are created equal

Calorie restriction is effective for weight loss. However, because it is difficult to adhere to long term, maintaining the weight loss requires a shift in strategy. Exercise, while not effective for weight loss, does work well to aid weight maintenance.

There are, of course, diets that simply restrict calories. This includes portion control – basically eating a little less of everything – which is very effective, but difficult to stick to. The issue is we have our recipes that we use, and it is difficult to reduce it by 20 per cent, say. Like if the original recipe called for one or two eggs, how do you reduce that by 20 per cent? So that means you have to serve yourself less, but that would leave 20 per cent of the unfinished meal in the pot, tempting you all night! That is why the use of meal-replacement shakes are popular. You simply make up an 800-calorie shake, and consume that. These shakes are nutritionally complete, and effective in the short-term. It is, however, very difficult for most people to stick to these shakes for any length of time, if only because of the monotony. So I think these shakes are useful to lose the weight initially, but alternative methods would be required to keep the weight off.

Another popular approach is group support, including programmes such as Slimming World and Weight Watchers. While each has their own unique selling point, they all harness the fact that you are more likely to do something if you are doing it with somebody else. It is important to remember that because public 'weigh-ins' are typically part of such programmes, they are going to be ill-suited to those who hate such events.

Then there are the intermittent fasting and time-restricted eating (TRE) approaches. The most common variation of intermittent fasting is the 5:2 diet, where one eats normally for five days, and then restricts calorie intake to 500-600 calories, for two days. TRE limits the amount of time in the day that one consumes food, typically to a six- to eight-hour window. Both undoubtedly create a calorie deficit for many people.

The question is, aside from the reduction in calories, are there any additional metabolic benefits? The underlying concept is that during the fasting phase you allow your body to use up the carbohydrates from your muscles and liver, stored in the form of glycogen, so you begin to burn fat instead. While there is some evidence of effectiveness of both diets in mice, the latest human studies do not see any significant advantage over and above the reduction in calories, for either intermittent fasting or TRE.

How about calorie counting, because aren't all calories equal? Well, all calories are equal once they are in us, as little poofs of energy. However, remember that we eat food and not calories, and some food takes more energy for our bodies to extract the calories from. This is why the source of the calories, whether from a steak, a carrot or a doughnut, makes an enormous difference. While calories are a useful reflection of portion size, they are not a marker of the nutritional content of the food. Instead, we have to take into account 'caloric availability', which is the amount of energy we can extract from a food, as opposed to the total number of calories in it. Digestion breaks food into its nutritional building blocks, all of which get moved across the gut wall into our blood. These building blocks are, however, just easily transportable intermediates that need to be metabolised to be converted into usable energy. This process of *producing* energy, also *costs* energy.

The two elements of food that have the biggest influence on calorie availability are protein and fibre. If we zoom out and take a broader view, it becomes clear that this concept goes far beyond an esoteric piece of nutritional trivia; rather, it explains how many popular diets work.

GETTY IMAGES, ALAMY

2 HIGH PROTEIN

This macronutrient can help you stay fuller for longer

Of the three macronutrients – carbohydrates, fat and protein – protein is chemically the most complex. Fat and carbs are made entirely of carbon, hydrogen and oxygen atoms, just in a variety of different configurations, thus metabolising or storing them is energetically efficient.

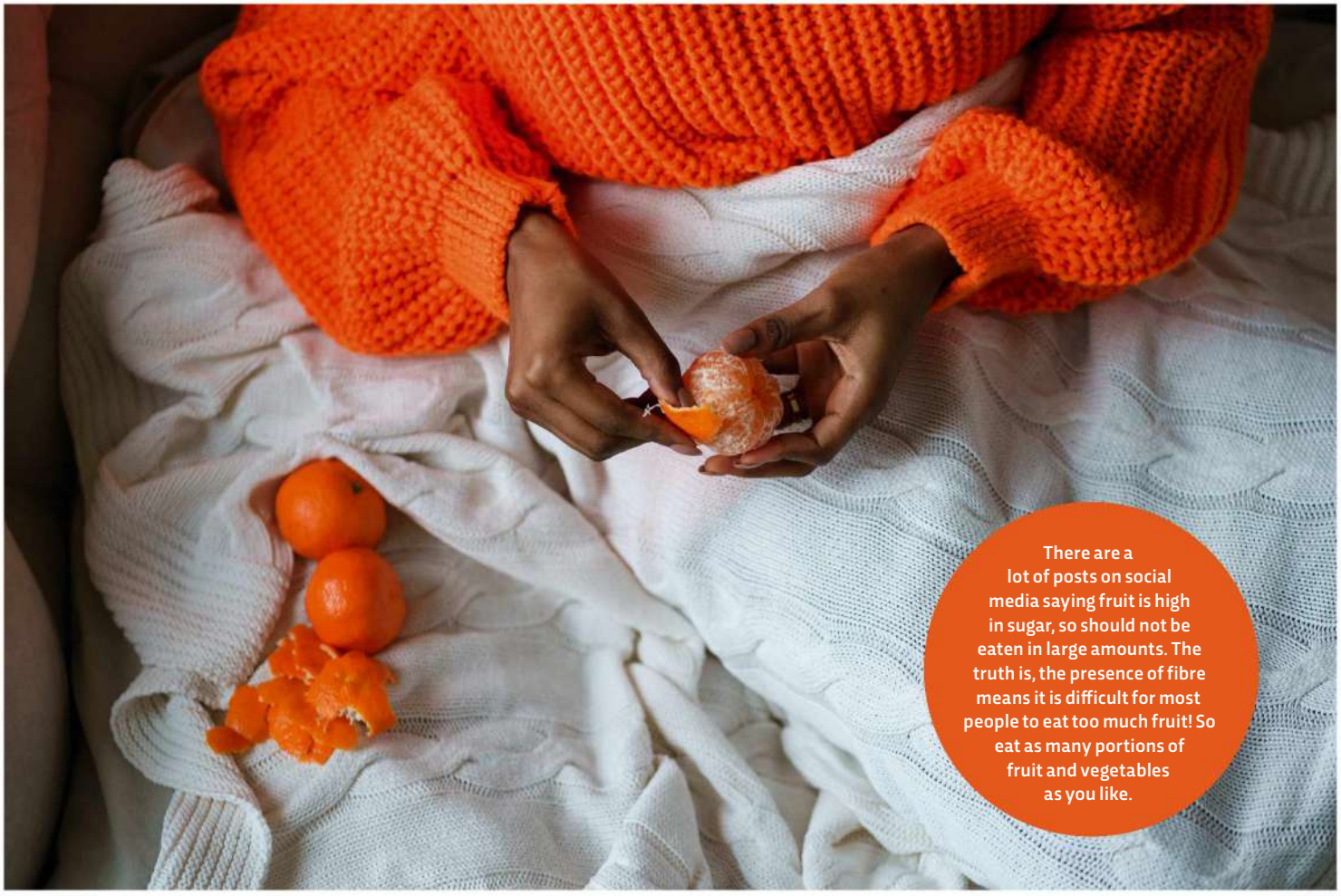
Unlike fat and carbs, all protein in our body is there for a reason, either for building or for repair – there is no passive store of protein for a rainy day. So any excess protein that is not used immediately has to be metabolised into energy or converted into fat. Second, while protein is, like fat and carbs, primarily composed of carbon, hydrogen and oxygen, it also contains a significant amount of nitrogen. This nitrogen needs to be removed, so is secreted as urea, primarily in our urine, before the remaining chemical structure of the amino acids can be converted into energy or fat. This process takes a lot of words to explain, and even more energy to deliver. In fact, for every 100 calories of protein that we consume, we are only ever able to use 70 calories, with the other 30 calories needed to handle the protein. Thus, protein has a caloric availability of 70 per cent. All the protein calorie counts we see today are 30 per cent out!

By comparison, fat has a caloric availability of 98 per cent, meaning that to convert it to energy costs next to nothing, and hence why it is such an efficient long-term fuel store. As for carbs, it all depends on whether we are talking about the complex (90 per cent available) or refined (95 per cent available) variety. The difference in this availability is down to the presence of fibre, which we mostly cannot digest and therefore passes right through us.

Diets that are high in protein include the entire menagerie of 'low carb, high fat' diets, ranging in severity of carb restriction from Atkins to keto to carnivore, but are all universally high in protein, defined as 16 per cent or more of total daily intake. For all intents and purposes, they also encompass diets like gluten-free (with the exception for those suffering from coeliac disease) and paleo.

These diets work for many people trying to lose weight because protein, from a chemical perspective, takes longer to digest and takes more energy to metabolise, so is more satiating than fat or carbs. You feel fuller, you eat less, you lose weight.

It's important to note that protein doesn't only mean steaks! Fish, tofu, beans and nuts are all rich sources of protein, but without the saturated fat found in land-based animals. Consider including a wide range of protein in your diet.



There are a lot of posts on social media saying fruit is high in sugar, so should not be eaten in large amounts. The truth is, the presence of fibre means it is difficult for most people to eat too much fruit! So eat as many portions of fruit and vegetables as you like.

3 HIGH FIBRE

Great for your gut, as well as your waistline

Fibre is actually a type of plant-based carbohydrate, although much of it is structured in a way that we humans cannot digest. Fibre is, of course, vitally important for our gut health, keeping everything shipshape and, ahem, regular. On average, we each only consume 15 grams of fibre a day, whereas we need to try and achieve 30 grams a day.

From the perspective of caloric availability, fibre slows down the rate of digestion, resulting not only in the release of nutrients over a longer period of time, but ultimately in a reduction in the absolute amount of calories absorbed.

An illustration of the impact of fibre can be seen when you compare drinking a glass of orange juice to eating a whole orange. When you drink juice, the sugar, which incidentally is at the same concentration as that of a fizzy drink, is absorbed by your body almost immediately. Eating an orange, however, first involves chewing, which is sensed by your body and allows it to prepare for the arrival of nutrients; and second, because the sugar is interlocked in the fibre, it takes energy and time for your digestive system to extract, thus you feel fuller. This is why dietary approaches that are high in fibre, including plant-based, low-GI and Mediterranean, as well as diets that are largely plant-based but with complex (and often false) back stories, such as alkali, work for weight loss.

"FIBRE SLOWS DOWN THE RATE OF DIGESTION, RESULTING IN THE RELEASE OF NUTRIENTS OVER A LONGER PERIOD OF TIME"

GETTY IMAGES ILLUSTRATION: GRACE RUSSELL

7 DIET RED FLAGS

With all the dietary information online, it can be hard to know what tips to follow. Watch out for these dodgy words and phrases…

DETOX

Any foods or supplements that claim to help 'detox' your body are red flags. Our liver and kidneys are our professional detox organs, and nothing we eat will change that.

SUPERFOODS

There are many foods that are 'good' for you, meaning that you can eat a lot of them – most fruit and vegetables sit in this category. There are, however, no such things as 'superfoods', which are simply foods with good PR.

FAT IS GOOD (OR BAD)

It doesn't matter if you are part of the fat is GOOD for you or BAD for you brigade, the important question to ask is the source of the fat. If it comes from a land-based animal, and is likely to be solid at room temperature, then it is saturated fat. Whereas if it comes from fish or plants, and it is likely to be liquid at room temperature (coconut fat is a rare exception), then it is unsaturated fat. All the evidence indicates that eating more unsaturated fat than saturated fat decreases 'all-cause mortality' – essentially, it lowers your risk of dying early.

NATURAL SUGAR IS BETTER

The vast majority of sugar we consume is sucrose. It is the white powdered stuff we cook with and have in our tea, and is made up of glucose and fructose. How about sugar from honey or maple syrup or agave nectar? They are often marketed as natural, so are better for you, or more curiously, as a 'sugar-free' alternatives (*Great British Bake Off* and your 'sugar-free week', I'm looking at you). This is simply not true. They do taste different from sugar because one is in effect bee puke, another is tree sap, and another concentrated cactus juice, so naturally each brings its own distinct flavour to different recipes. But they are all sweet because of glucose and fructose.

HIGH-PH (ALKALI) WATER

At a pH of 7.4, our blood is slightly alkali (less than 7 is acidic, more than 7 is alkali). Some people therefore think we need to eat alkali foods, and that includes drinking water with a high pH. Don't drink the Kool-Aid! Everything we eat or drink passes through the stomach, which, at a pH of 1.5, is the most acidic part of the body. It is then neutralised to a pH of 7 when it enters into the small intestine. Nothing we eat will change the pH of our blood. Don't waste your money on alkali water and diets.

DON'T EAT ANYTHING YOU CAN'T PRONOUNCE

This is part of the push to eat 'natural' or 'clean' foods. But whether they're natural or highly processed, all foods are full of chemicals, you just don't happen to know the scientific names for them. For example, should you fear 'phenylthiocarbamide', because you can't pronounce it? This is simply the chemical responsible for the bitter taste found in brassicas, the plants in the cabbage and mustard family. This type of advice is simple scaremongering.

DON'T EAT FOOD WITH MORE THAN FIVE INGREDIENTS

Simple foods can be very tasty indeed, but they are not necessarily healthier for you. If I, for instance, use Chinese five spice powder in a recipe, that would presumably count as one of the five ingredients. However, what if I added the typical components of five spice powder, so star anise, fennel seeds, Szechuan peppercorns, cloves and cinnamon, separately into a dish?
Does that mean my recipe suddenly becomes bad because it has more than five ingredients? **SF**

—

by **PROF GILES YEO** *(@GilesYeo)*

Giles is a professor at the University of Cambridge, whose research focuses on food intake, genetics and obesity. He is a broadcaster and author, and his latest book is Why Calories Don't Count *(£14.99, Orion).*

DOWN ON THE ROBOT FARM

by HAYLEY BENNETT

IN THE WEST, FARM WORKERS ARE IN SHORT SUPPLY... BUT ROBOTS ARE READY TO TAKE THEIR JOBS

ROBO-CROP

In the last 70 years, agriculture has lost the majority of its workforce as generation after generation has turned away from family farming businesses. Despite this, agriculture has found ways to increase food production, with machines playing a key role. But in 2020, the United Nations warned that agricultural productivity would need to increase by 60 per cent in order to feed the predicted global population in 2050. With big producers like the US still struggling to find agricultural labour, that demand simply can't be met if farming doesn't change how it operates.

"There's still a massive gap between the labour that agriculture *needs* and the labour that agriculture *has*," says Walt Duflock, vice president of innovation at Western Growers, a crop growers' association covering the western US. "So labour is a huge problem and automation's the only solution to close the gap."

This is why farmers are now swapping more traditional machinery for modern, AI-powered farming robots adept at some of the tasks that once required human hands. The Naïo Oz Farming Assistant pictured here, for instance, is designed for hoeing, weeding, making furrows, seeding and transporting. There are nearly 150 of these robotic farmhands in circulation across 48 countries.

PETER ADAMS

Z440

TECHNO TRACTOR

Tractors have been driving themselves for decades – John Deere developed a GPS-based self-guidance system in the early 2000s. But they haven't generally been doing it unmanned. "There's always been a person in that tractor," says Kantor. "It's basically driving itself – the person is sitting there and they're doing other things – but [the tractor] is not quite a robot."

A new breed of autonomous tractors, however, is set to change that. Specifications for the Monarch Electric Tractor (pictured right) state that a driver is 'optional'. It's battery-powered, with 360° cameras that can be accessed live by an operator via the software the manufacturer supplies. So now 'driving' a tractor is beginning to take on a whole new meaning, as we envisage farm workers managing whole fleets of vehicles without ever needing to lay their hands on a steering wheel. Monarch claims operators can easily keep tabs on eight tractors at once via its Wingspan AI app, which provides maps and helpful data, such as distance covered and energy used.

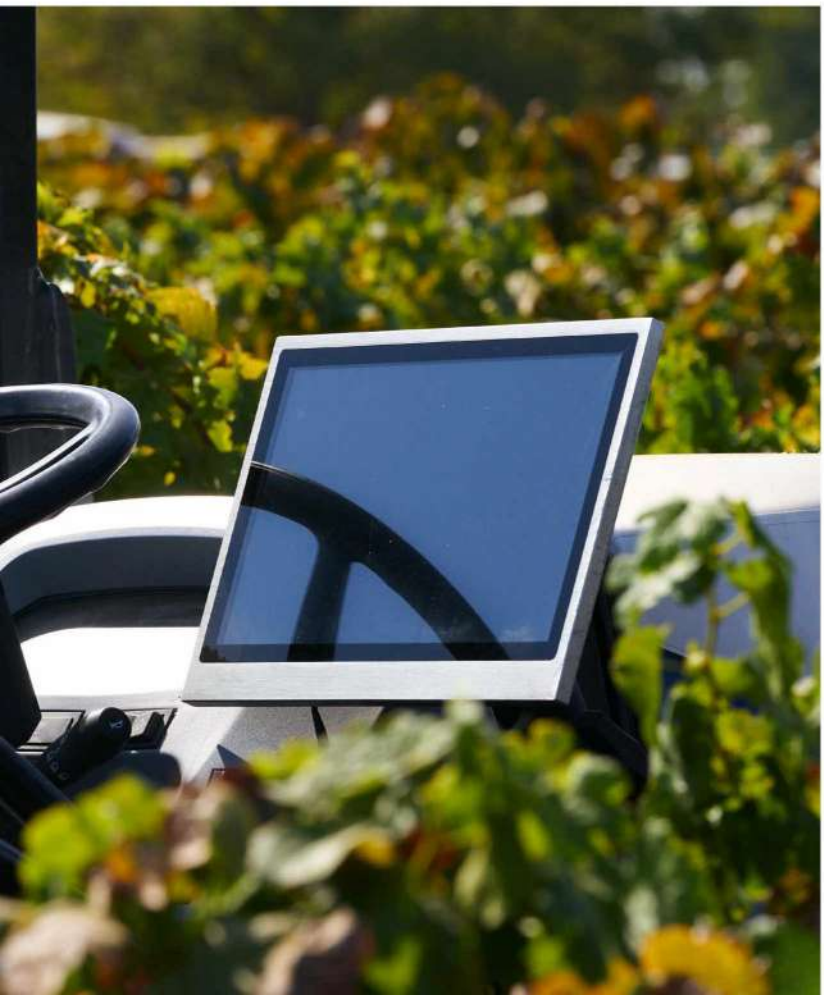
MULTIPURPOSE MACHINES

As well as an ever-increasing number of 'AgTech' start-ups, there are also more established manufacturers that have sold hundreds of robots, like Naïo (see previous page) and Burro, which makes helper robots for tasks like towing and carrying.

Stout Industrial Technology, which sold its first Smart Cultivator (pictured left) in 2020, is also heading in the same direction. The cultivator can be hitched to the back of a tractor, where it uses computer vision and AI to precisely control mechanical blades as they turn over soil and eliminate weeds, while sparing crops. Stout's approach is 'software-defined' – it builds multipurpose farming machines that will become more useful as the AI improves.

Field robotics expert George Kantor, from Carnegie Mellon University in Pittsburgh, thinks this is the right approach, although not the simplest one.

"The easy way to do it is to build a special purpose machine for every application and then use intelligence to automate that machine, but of course there are thousands of different applications in agriculture and very few of them are big enough to build a business around," he says. "So you have to find ways of making the machine be applicable across tasks and across crops."



PETER ADAMS X3

TOP OF THE RANGE

Why pull your weeds out of the ground by hand when you can have them zapped with pinpoint precision by a laser-wielding robot? Carbon Robotics' Laserweeder uses high-resolution cameras and computer vision software to tell weeds from crops, then blasts them into submission. While the demo version (pictured above) is an autonomous unit, the 2023 model comes in an 'implement' format that can be hooked up to a tractor. At $1.4m (£1.2m approx), it doesn't come cheap, but it can kill 200,000 weeds per hour. This makes it popular enough that there's a year-long waiting list for orders, according to Duflock.

It's simply a question of maths for growers, who are having to postpone their weeding because they can't get the labour. "They run the maths against the crew," he says. "And what they're telling me is the breakeven on a couple of hundred acres looks to be two or three years."

So while those with bigger operations – more like 5,000-10,000 acres (20-40km^2) – are going to be the early adopters, once the technology is proven, smaller scale growers are bound to jump on-board too.

FIELD OF DREAMS

Weeding and thinning out of crops are some of the tasks that agricultural technology companies are starting to get a handle on. According to Duflock, while harvesting might be causing more of a headache, new farming technologies will have these more straightforward applications 'figured out' within the next decade. This will mean higher upfront costs for farms, but will also reduce reliance on temporary workers from other countries, which in the US comes with associated housing and transport costs under a government visa scheme.

But if cash-strapped farmers don't have a cool million to lay out on a Laserweeder, then the Farmwise Titan FT35 Agtech Robot (pictured right) offers a mechanical weed-killing solution suited to a tighter budget. Combining a self-driving tractor and weeding attachment, it's a hefty-looking robot but is still capable of precision weeding. It can also apply chemicals to kill weeds and pests. Because lighting levels need to be optimum for sensing the weeds, the FT35 has a 'skirt' that can be raised and lowered to offer some level of control over the amount of light getting in.

PETER ADAMS

WARNING

SAFETY FIRST

New farming technologies are not without risk. That's why they're built with safety features, like the emergency stop button (pictured far right) on Robotics Plus's tree and vine sprayer, or the 'human detection' system on Monarch's electric tractor, which puts the brakes on when a person gets too close. There are less obvious risks too. As agriculture becomes increasingly data-driven, companies are showing interest in aggregating all this new data. While there are plenty of intelligent things we could do with massive agricultural datasets – like predicting the impacts of climate change on crop growth – there are also concerns it could be exploited, for instance, by insurers who set the premiums for crop losses or flood damage. Though Duflock notes that if farmers "get smart enough" and share their data safely, they could use it as an additional revenue stream. Meanwhile, concerns about robots taking our jobs may be unfounded in an industry that is desperately short of labour – in fact, they may create fewer but more highly skilled, better paid jobs.

"In 10 years, I do think immigrant farm labour will still be a huge factor on the farm," Duflock says. "But I think there'll be a lot of robots that enable those workers to do more things that are valuable." **SF**

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PETER ADAMS X4

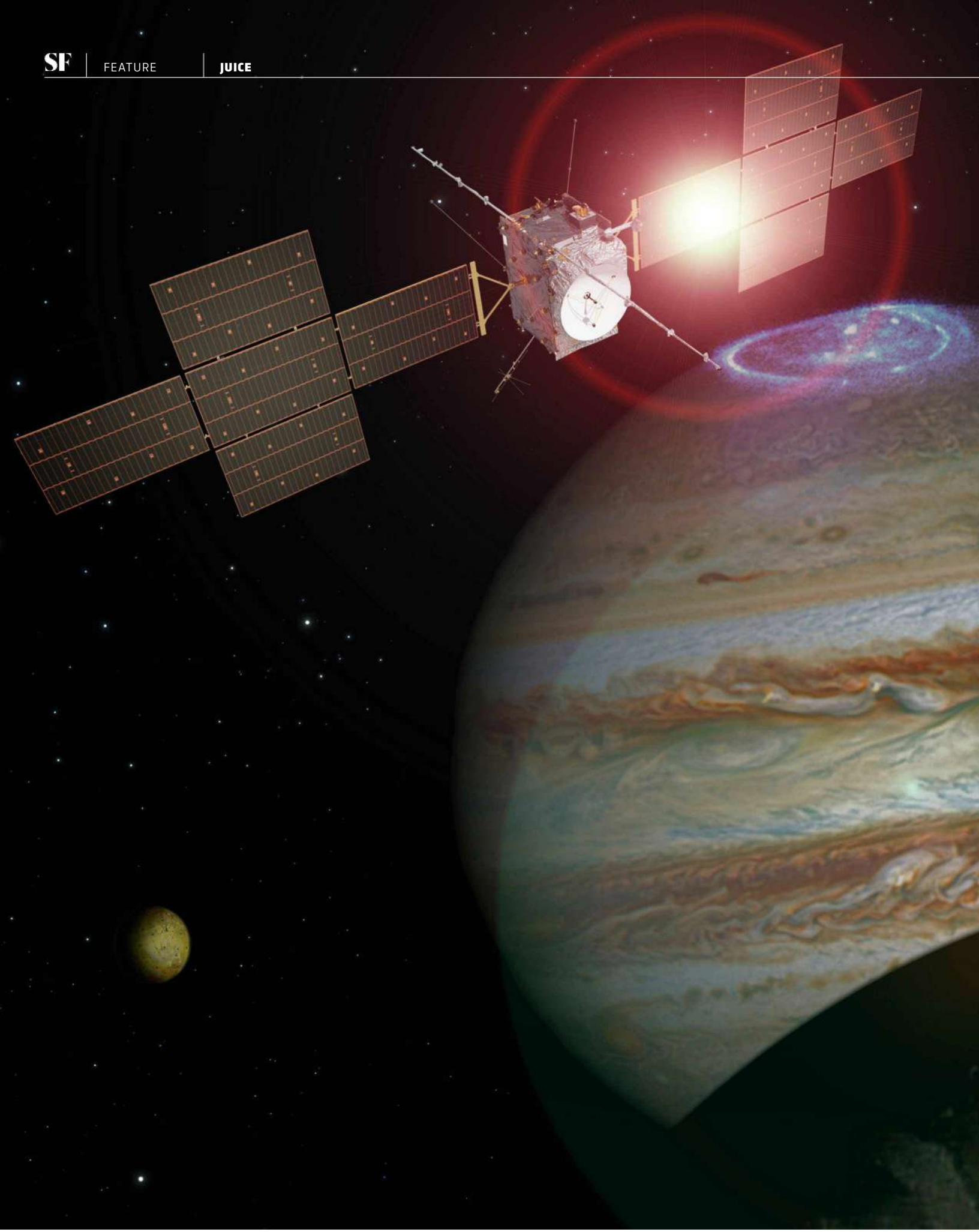
OPTIMUS VINE

Vineyards present different challenges from other forms of farming, but agricultural robots like the Vitibot (pictured left) are specially designed to deal with at least some of them. This autonomous electric robot trundles along each row, tilling the ground as it goes, but can also be fitted with tools for spraying, weeding and trimming.

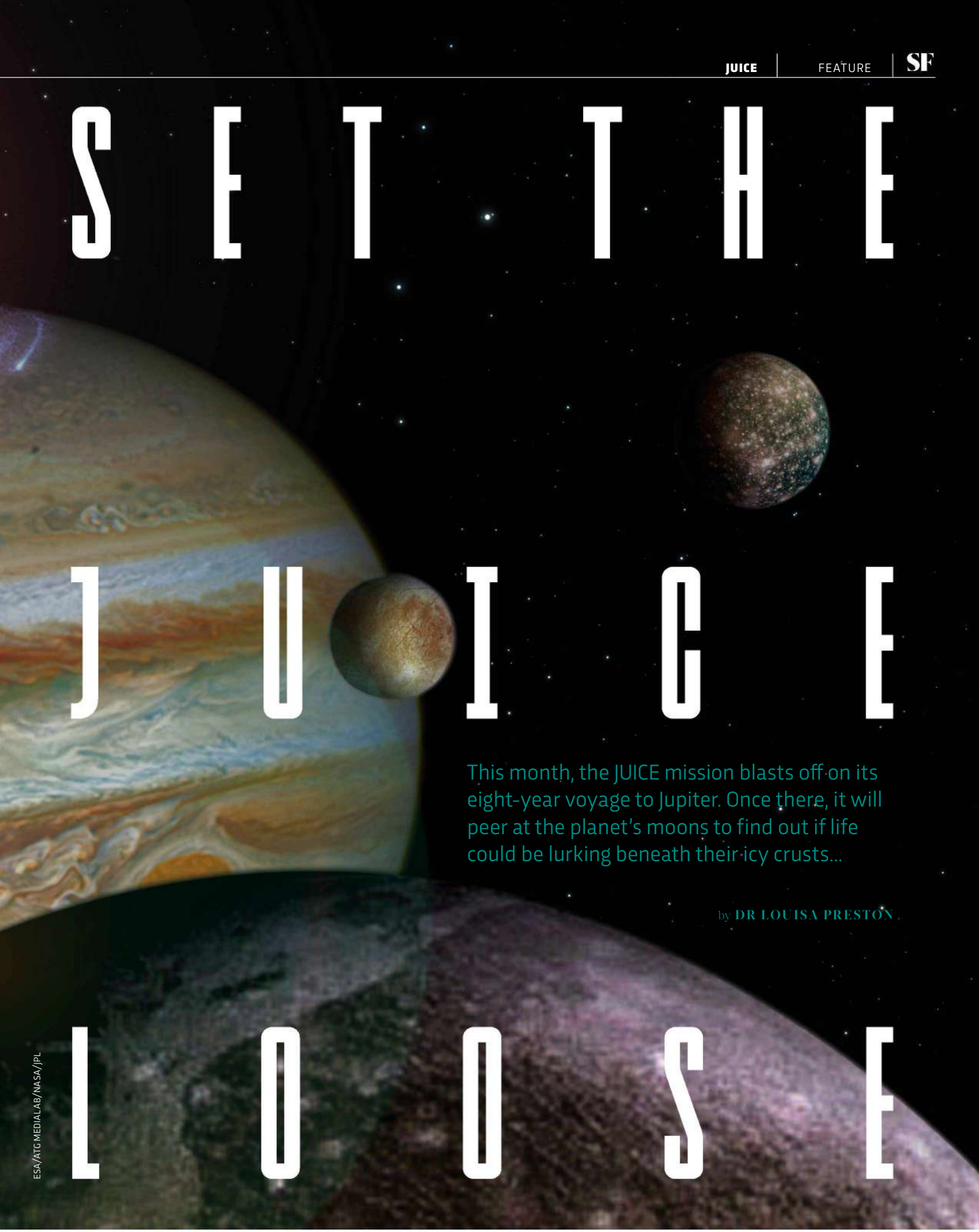
Harvesting grapes is another matter. Grapes come in two varieties: wine grapes (which are crushed) and table grapes (which are eaten whole). For wine grapes, it's already possible to buy robotic harvesters. French company Pellenc sells one that wine producers have used to harvest their grapes, while Duflock says manufacturers will probably come up with service models that smaller growers can borrow to harvest their crops at lower cost.

Table grapes require a slightly gentler touch. As Kantor explains, human harvesters carry out a number of important tasks as they're picking the grapes off the vine. "They would cut a bunch off the vine, clean the cluster, make it the right shape and size, cut out the dead grapes and get the sticks out," he says. "You can imagine a robot that takes the cluster off the vine today, but I can't imagine a robot that does that other really fine stuff – not any time soon."

by HAYLEY BENNETT
(@gingerbreadlady)
Hayley is a freelance science writer based in Bristol.



SET THE JUICE LOOSE



This month, the JUICE mission blasts off on its eight-year voyage to Jupiter. Once there, it will peer at the planet's moons to find out if life could be lurking beneath their icy crusts...

by DR LOUISA PRESTON

ESA/ATG MEDIALAB/NASA/JPL

The Earth has always been believed to be the gold standard for a habitable world. Lessons learnt from life on Earth have told us that if we want to seek life on other planets in the Solar System, we need to find three basic ingredients in the same place at the same time – liquid water, the chemical building blocks of life, and a source of energy. Previously, we thought that these could only be found within a narrow ring around the Sun called the 'Goldilocks Zone', or 'Habitable Zone'. But we were wrong.

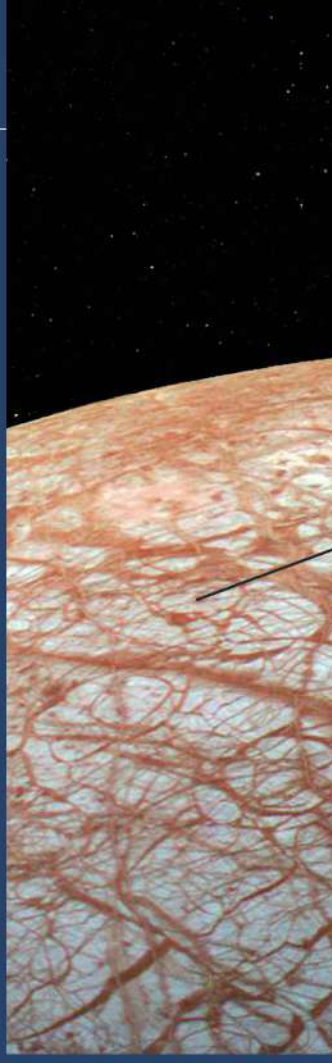
Images of Jupiter's moons taken by the Voyager missions in 1979 and the Galileo spacecraft between 1995 and 2003 completely reshaped our view of the Solar System. They exposed evidence for liquid water in the outer reaches of our planetary neighbourhood, far from where we thought it should be able to exist. Today, we know that the fourth largest moon of Jupiter, Europa, contains more water than all of Earth's oceans combined. It turns out that Jupiter, despite being outside our Solar System's traditional habitable zone, has created a habitable zone all of its own, driven not by the Sun's warmth – sunlight at Jupiter is 30 times dimmer than at Earth – but by the effects of its incredibly powerful gravity. Given these new 'cooler' habitable options, in April this year the JUpiter ICy moons Explorer (JUICE) mission will be sent to Jupiter's moons to help astrobiologists understand how habitable worlds have emerged in the outer Solar System.

JUICE will uncover the biological effects of the interaction between a planet and its moons by exploring three of Jupiter's icy moons: Ganymede, Callisto and Europa, and their watery subsurface environments. Ganymede will take a fair share of the focus of JUICE, but the results it might obtain from Europa, in collaboration with NASA's Europa Clipper, will be incredibly exciting as it will be the first time we are able to study present-day environments suitable for life beyond the Earth.

WATER WORLD

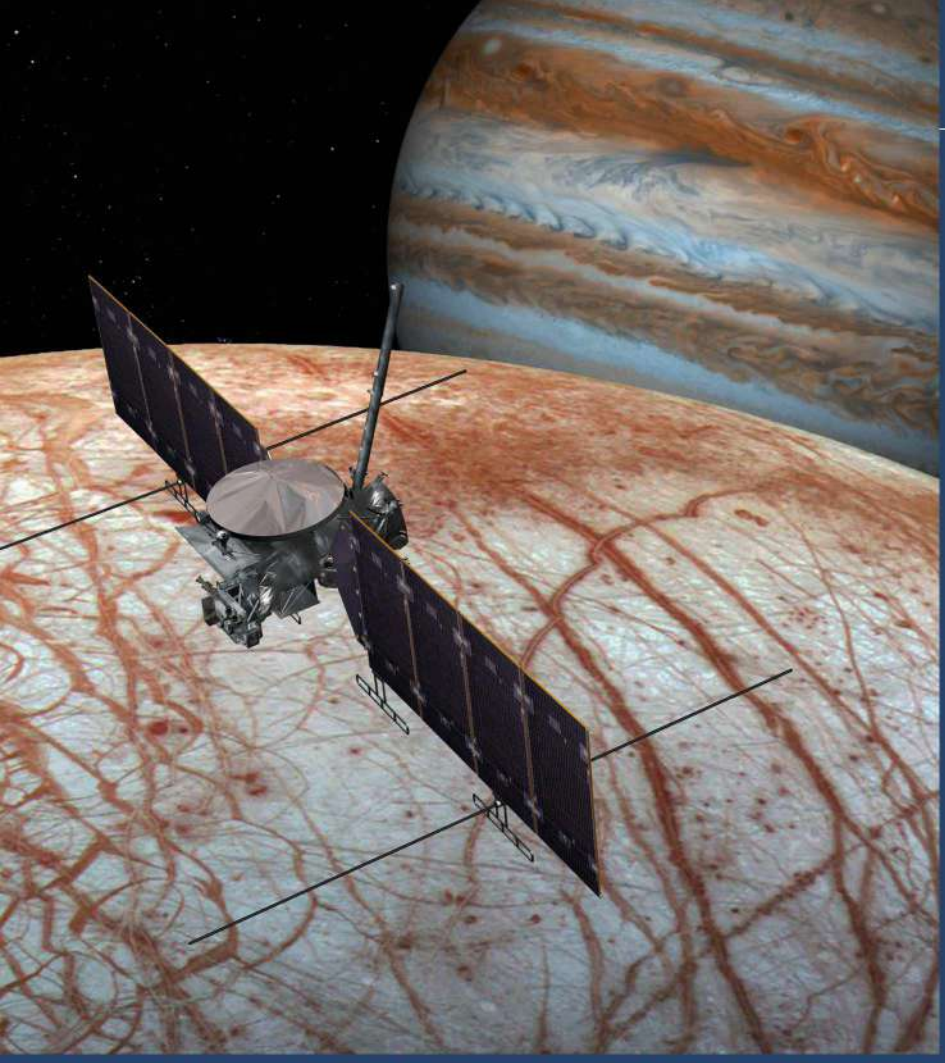
Liquid water is at the top of the astrobiological wishlist when exploring other planets, as it dissolves nutrients and transports chemicals within the environment. Water could help to store and circulate the chemicals for life throughout a planetary body, and Europa has water aplenty.

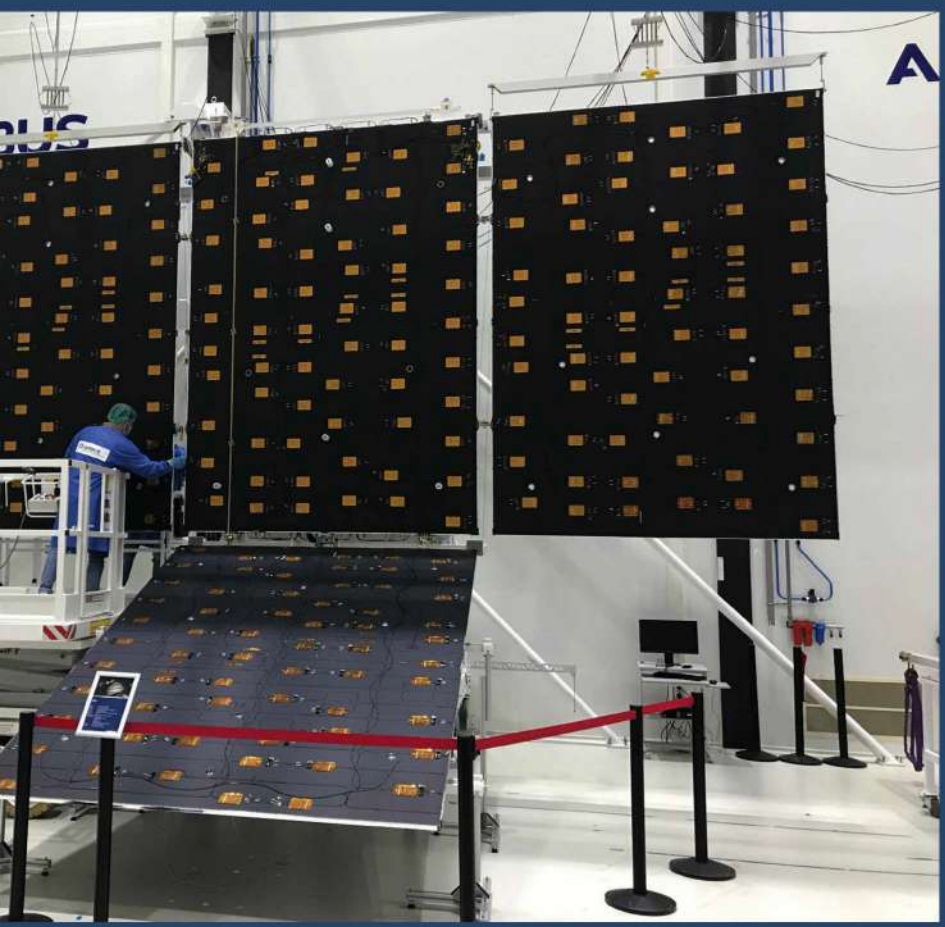
A large part of Europa's water is frozen, creating a bright, icy crust; a landscape unlike anything the Earth has to offer. This glacial shell encompasses the entire moon and is thought to be between 16 and 24 kilometres thick, but is floating atop a salty liquid ocean between 64 and 160 kilometres deep that is in direct contact with a rocky seafloor. The most striking features of this ice are the criss-crossing double ridges and grooves of reddish brownish non-ice material (water mixed with magnesium sulphate and sulphuric acid, for example) that scar the surface. Recent studies of similar ridges on the Greenland icesheet have hinted that these might be created by pockets of liquid water near to the surface of the ice shell



"JUPITER, DESPITE BEING OUTSIDE OUR SOLAR SYSTEM'S HABITABLE ZONE, HAS CREATED A HABITABLE ZONE OF ITS OWN"

NASA/JPL, AIRBUS DEFENSE





ABOVE LEFT As seen in this artist's impression, one of the most striking features of Europa is the array of reddish coloured lines that criss-cross the surface

LEFT JUICE's solar panels, of which there will be 10 in total, provide the power to run the spacecraft and operate its scientific instruments

being squeezed upwards from the underlying ocean through fractures in the ice.

It is generally agreed that there is an ocean within Europa, but we haven't directly seen it yet. The best evidence that this ocean exists is indirectly due to the observation that a magnetic field is created within Europa as Jupiter's powerful magnetic field sweeps past the moon – a global ocean of salty water is the most likely thing that could create this.

In addition, there is growing evidence for plumes of water vapour erupting from its surface, similar to those most commonly associated with one of Saturn's moons, Enceladus. The icy surface also appears to be young, or at least parts of it are. It doesn't have many impact craters on it like other moons, which means geological activity such as warmer ice rising from an ocean below, could be erasing the craters and allowing Europa to maintain its relatively youthful appearance.

RADIATION AND REACTIONS

As with any planetary body, Europa may have a number of processes that are working together and independently to make the energy needed for powering life. Yet given how far the moon is from the Sun, this life won't be powered by photosynthesis using solar heat, but most likely by chemical reactions occurring across the surface and within the ocean. Europa's surface is blasted by radiation from Jupiter which interacts with the icy crust and other materials, altering them into some of the chemical building blocks of life including free oxygen, hydrogen peroxide, carbon dioxide and sulphur dioxide. The oxygen, for example, if it makes its way to the ocean, could be used in chemical reactions that release energy for life to exploit.

Reactions between the salty water and the rocky ocean floor could also create nutrients to support life. The ocean interacts with hot rock emanating from the sea floor, then that water could be pouring out chemical nutrients that can power life, just like the hydrothermal vents in Earth's oceans. Internal heat energy from Europa, perhaps enough to help maintain the liquid ocean in the first place, could also be useful and would be created as the icy moon gets squeezed in and out by the tug of Jupiter's gravity, in a process called tidal flexing. →

Journey to Jupiter

Everything you need to know about ESA's much-anticipated JUICE mission

Words Catherine Regan
Infographic James Round

What is JUICE?

JUICE, or the JUpiter ICy moons Explorer, is a European Space Agency (ESA) mission that will travel to Jupiter and its moon system with various instruments to help us understand gas giant systems. It will be launching on 13 April 2023. Although it is an ESA-led mission, there have been engineering contributions from NASA and JAXA

To help us understand our own Solar System and gas giants across the Universe, JUICE will be studying Jupiter's environment, in addition to some of its icy moons. The mission's theme is 'the emergence of habitable worlds around gas giants', as it is thought that moons such as Europa are likely to contain signs of life.

JUICE will be the first spacecraft ever to orbit a moon in the outer Solar System, when it changes orbit from Jupiter to Ganymede at the end of the nominal mission.

In 2024, the Europa Clipper will blast off, arriving at the moon in 2030 to carry out further research.

JUICE: IN NUMBERS

10 The number of scientific instruments carried by JUICE, from spectral imaging tools to radar. Find out more about these tools on the opposite page.

8 years The total duration of JUICE's mission. In that time it will have been to Venus and back to Earth (twice!), before reaching Jupiter and its moons.

85m² The impressive size of JUICE's solar panels. JUICE has to operate where sunlight is 25 times weaker than on Earth, so it needs to be able to collect lots of light.

-230°C The temperature that JUICE will have to operate in while in the orbit of Jupiter. However, during its Venus flyby, the temperature will be +250°C!

>2,000 The number of people who worked on the JUICE mission. This ESA-led, global collaboration included 18 institutions, 23 countries and 83 companies.

JUICE is the latest in a long line of ambitious missions involving Jupiter, starting with the first flyby by Pioneer 10 in 1973. In 1995, Galileo became the first spacecraft to orbit Jupiter, with the broad aim of studying the planet and its moons. And Juno followed two decades later to further investigate the gas giant.

A visit to Venus

In August 2025, JUICE will perform a flyby of Venus, where it will receive another gravity assist.

04

03 **Lunar-Earth flyby**

In August 2024, JUICE will perform a flyby of the Earth-Moon system, known as a Lunar-Earth gravity assist (LEGA) – the first ever to be carried out.

All systems ready!

02

After launch, it will take JUICE around 2.5 weeks to complete the deployment of its antennas, probes and magnetometer boom.

JUICE will be launching on an Ariane 5 rocket, the 'workhorse' of the ESA. After 110 successful launches, this launch will be Ariane 5's last, as it is due to be replaced by the new Ariane 6.

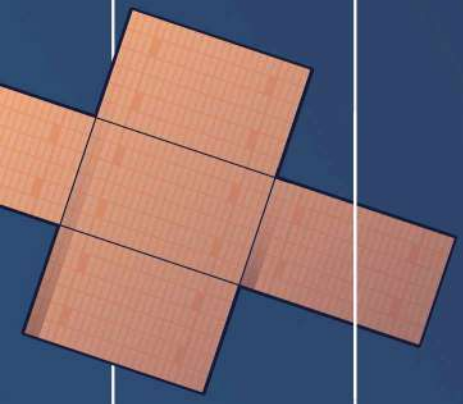
What will JUICE's journey look like?

During its eight-year journey, JUICE will take in some of our Solar System's most spectacular sights, as it uses the gravity of other planets and moons to help it reach its final destination.

Start here

01 **Lift-off!**

JUICE will be launching from French Guiana, which is Europe's spaceport, within the launch window in April 2023.



05

Next stop... Earth?

JUICE will then travel back to Earth, where it will perform not one, but two flybys in September 2026 and January 2029. These gravity assists allow the craft to save a significant amount of propellant on its journey.

06

Welcome to Jupiter

In January 2031, JUICE will begin its science phase, before reaching Jupiter in July.

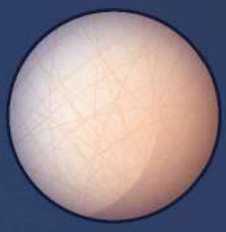
07

A Jovian joyride

JUICE will perform 35 flybys as it explores Jupiter's moons, then will settle into orbit around Ganymede in 2034.

! JUICE will be focusing its attention on three of Jupiter's moons – Europa, Callisto and Ganymede – but it's estimated that the gas giant has more than 90 moons, the most of any planet in our Solar System!

Europa

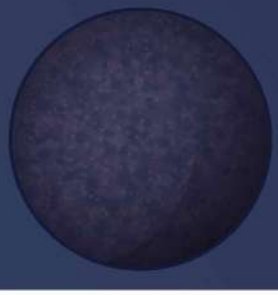


It's believed that this moon could potentially support life, so JUICE will be looking for evidence of organic molecules and other biosignatures within the ice, and also within water vapour that Europa may vent into space.

Number of flybys
2

Closest approach
400km

Callisto



With the oldest and most heavily cratered surface in the Solar System, JUICE will be investigating Callisto to better understand the features and environment of the early Jovian system. It will also study its structure, composition and chemistry.

Number of flybys
21

Closest approach
200km

Ganymede

Ganymede is the only moon in the Solar System to generate its own magnetic field. JUICE will analyse this, along with the moon's atmosphere, complex core, its ice content, and the potential of a subsurface ocean.

Number of flybys
12

Closest approach
400km

What tools does JUICE have on-board?

JANUS
This optical camera system will be JUICE's eyes, studying the features of the moons, as well as the clouds of Jupiter itself.

UV imaging spectrograph (UVS)
This will study the composition and dynamics of the moon's exospheres, as well as Jupiter's atmosphere and beautiful aurorae.

Moons and Jupiter Imaging Spectrometer (MAJIS)
This will be used to study the atmospheric features of Jupiter, as well as the ice and other minerals found on the Jovian moons.

Sub-millimeter Wave Instrument (SWI)
This will measure the atmosphere of Jupiter and the exospheres of its moons, to determine their structure and composition.

Ganymede Laser Altimeter (GALA)
This tool will help to provide evidence for subsurface oceans within the Jovian moons. It will also map the topography of the moons.

Radar for Icy Moons Exploration (RIME)
This ice-penetrating radar can see nine kilometres below the surface, in order to discover the subsurface features of the moons.

JUICE Magnetometer (J-MAG)
This will allow JUICE to study the magnetic fields of Jupiter and Ganymede, and how they interact with each other.

Particle Environment Package (PEP)
This includes a number of sensors to characterise the plasma* environment of the Jupiter system.

Radio and Plasma Wave Investigation (RPWI)
This will characterise radio emissions of Jupiter's magnetic field and the plasma* environment on Jupiter and its moons.

Gravity and Geophysics of Jupiter and Galilean Moons (3GM)
This will study the gravitational field of Ganymede, and the atmospheres and ionospheres of Jupiter and its moons.

**A plasma is a partly or wholly ionised gas whose particles exhibit collective responses to magnetic and electric fields.*

→ In addition to liquid water and energy, for Europa to be potentially habitable, it needs to have the essential elements for life – carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur. We think these were present on the moon as it formed, with more added over billions of years by the impact of comets and asteroids; and will be found within its icy shell, watery ocean and rocky core.

GOING UNDERGROUND

On the face of it, Europa isn't welcoming to life. Its surface is bathed in extreme radiation and daytime temperatures barely surpass -160°C. None of the currently known terrestrial extremophilic lifeforms could survive these harsh conditions, and as such we think that any life on Europa will be relegated underground where more protected and relatively clement environments can be found. Studies on the Earth have reinforced this idea. Since the 1970s we have discovered more than 370 lakes hidden beneath several kilometres of glacial ice in Antarctica (many with microbial life within them), bacteria living in sandstones in the cold, dry, inhospitable Antarctic Dry Valleys, and thriving ecosystems around hydrothermal vents deep beneath the world's oceans.

The Earth has shown us that life lives in colder, darker, stranger places than we ever dreamed. Today, the idea of life floating around in the liquid ocean under Europa's ice crust or crowding around mineral-and energy-

LEFT Jupiter with its four largest satellites, known as the Galilean moons. From top to bottom: Io, Europa, Ganymede and Callisto

BELOW Artist's impression of Europa's icy surface crust

BOTTOM RIGHT Core of the Ariane 5 rocket, which will blast JUICE into space in April this year

rich hypothesised deep-sea vents, is widely considered the most promising reservoir for life beyond Earth.

What could this life look like? Honestly, who knows. Logically, we think it will be mostly or entirely microbial, like the most extreme-loving life we find on the Earth in Europa-like environments. However, it is always fun to speculate. Europa's global ocean may have been in existence for billions of years, more than enough time for evolution to get to work. Europa could have a vigorous biosphere hidden inside its watery depths supporting larger forms of life – perhaps it is filled with Europan octopuses? It is, of course, unlikely, but we cannot be closed off to this possibility. What is exciting about Europa, is that the life we are talking about is not ancient life or the signatures of its past existence left behind in the minerals and ice, but life that could be living today!

"EUROPA COULD HAVE A VIGOROUS BIOSPHERE HIDDEN INSIDE ITS WATERY DEPTHS"

HUNT FOR LIFE

In July 2031 when JUICE arrives in the Jovian system, the solar-powered spacecraft will combine the power of all 10 of its science instruments to uncover the hidden subsurface oceans and habitability potential of Europa, Callisto and Ganymede. JUICE will perform two Europa flybys and work in collaboration with NASA's Europa Clipper mission (which sets off in 2024 and arrives in 2030), before culminating its tour with an orbital insertion around Ganymede, its final stop.

Since we are not landing on Europa anytime soon and cannot drill into the ice or directly sample the ocean, we will need to make observations of the surface remotely and sample indirectly. High-resolution mapping of the surface at multiple wavelengths can help us figure out the composition of the ice and the non-ice reddish material, and assess how habitable the moon could be by searching for biosignatures and determining the distribution of biologically essential elements.

We can also use ice-penetrating radar to map the subsurface structure of the moon down to nine kilometres. We might also be able to get a taste of Europa's ocean, because it is possible that it may be leaking out into space. In November 2019, NASA announced it had directly detected water vapour for the first time above Europa's surface, and we are pretty sure that thin plumes of water are being ejected into space. If the plumes do exist, then JUICE could investigate the dust and other substances being erupted, and if that material originates from the ocean, it could contain molecules that are indicative of life.

Although JUICE isn't designed to find extraterrestrial life, it *will* help us assess Europa's habitability. It will allow us to learn more about the ocean-surface boundary, to what extent the conditions are suitable for biology, and will reveal how geologically active Europa's interior is.

As scientists, we are always having to change and adapt our thinking, especially with regards to habitability and the extent and limits of life. Thanks to Europa and the future data from JUICE, we are exponentially expanding our catalogue of potentially habitable worlds, not just in our Solar System, but in other solar systems across the Galaxy. If through JUICE and subsequent missions and observations we one day find that life arose on Europa, then life in the Universe could literally be everywhere! If we discover that life didn't arise on Europa despite all the right conditions, then we will truly marvel at just how unique and special the Earth really is. SF

NASA/JPL KX2, ESA/CNES/ARIANE SPACE/P BAUDON

by DR LOUISA PRESTON
(@LouisaJPreston)
Louisa is a lecturer in planetary science and astrobiology at UCL's Mullard Space Science Laboratory. Her book, Goldilocks And The Water Bears *(£9.99, Bloomsbury Sigma), is available now.*

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Q&A

YOUR QUESTIONS ANSWERED

... WHAT IS A DORMANT BLACK HOLE?
... WHY CAN'T ROBOTS ON MARS CLEAN THEMSELVES?
... WHY DOES SUGARY PUFFED WHEAT CEREAL MAKE MY WEE SMELL?
... WHERE SHOULD YOU STORE YOUR EGGS?
... HOW DO SHARK TEETH WORK?
... WHY DO I GET SO JEALOUS?
... WHY IS LITHIUM SO RARE IN THE UNIVERSE?
... WHY CAN'T YOU EAT OR DRINK BEFORE A GENERAL ANAESTHETIC?
... HOW INCOGNITO IS INCOGNITO MODE?
... CAN THE CLOTHES YOU WEAR REALLY AFFECT YOUR MOOD?
... WHY DOESN'T FUSION GENERATE RADIATION?

Email your questions to

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ILLUSTRATION: DANIEL BRIGHT

MANDY WILSON, LONDON

IS THERE ANYTHING I SHOULD AVOID AT LUNCH, TO DODGE THE AFTERNOON SLUMP?

It sounds as if you suffer from the common affliction of postprandial somnolence, otherwise known as a food coma. Postprandial somnolence is not completely understood in humans, although there have been experiments on rodents, fruit flies and nematode worms.

A meal filled with high-carb and high-sugar foods, such as potatoes, breakfast cereals and white bread, may be more likely to make you slump. These foods have a high glycaemic index, rapidly releasing sugars in the body. The spike in blood glucose instructs the body to produce more insulin, which sets off a chain of biological events leading to muscle and fat cells taking up glucose. This can cause blood sugar levels to crash, leading to low energy.

When you eat, your body activates its parasympathetic nervous system and enters a 'rest and digest' mode, which contrasts with the sympathetic nervous system's 'fight or flight' mode. The extent to which the rest and digest mode induces sleepiness depends on how much food you eat in one sitting. More food requires more rest.

The amino acid tryptophan may also play a role in postprandial somnolence. Tryptophan is present in many protein-based foods, including eggs, fish and meat. Insulin stimulates the uptake into muscle of some amino acids, but not tryptophan. This leaves tryptophan available to travel on an amino acid transporter, into the brain. There, it converts to serotonin and melatonin, both of which increase relaxation and sleepiness.

The best way to avoid a food coma is to avoid having high-carb meals, like sandwiches or rice. Add in some protein, healthy fats and vegetables to balance things out, and don't eat too much in one sitting. ***ED***

DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY OUR EXPERTS

LIZZIE WHITE, VIA EMAIL

WHY DOES SUGARY PUFFED WHEAT CEREAL MAKE MY WEE SMELL?

Your urine can change colour and smell according to what you eat. Foods like beetroot, blackberries, and broad beans can turn urine pink or red, for example, as the pigments are excreted by your kidneys.

But if truth be told, your urine shouldn't really smell sweet. Google brings up various anecdotal articles about sugary cereals making our urine smell like them, but this has not been scientifically proven. You might want to consider getting checked for diabetes if you really think this is the case.

Diabetes results from issues with the hormone insulin and leads to more blood glucose circulating in the bloodstream. When these blood sugar levels get really high, the body tries to find balance in any way that it can, including through the urine. Urine that contains glucose may well smell sweet because it actually contains sugar. But since that is not a normal route for glucose to leave the body, it's a sign that warrants further investigation.

Some medicines can give urine vivid tones too, such as orange or greenish-blue. For example, the information leaflet for the cold medicine Day Nurse states that: "One of the excipients of this medicine (Riboflavin 101) may cause your urine to turn bright yellow/orange. If this continues even after stopping taking this medicine, you should contact your doctor". So this one isn't something to be worried about! Riboflavin is a water-soluble vitamin, and excess amounts are excreted by the kidneys. As riboflavin is bright yellow in colour, it can make your wee luminous while you're taking the Day Nurse. ***NM***

ELEANOR SMITH, VIA EMAIL

WHAT IS A DORMANT BLACK HOLE?

Black holes, although emitting no light of their own, interact with their environment because of their enormous gravitational fields. They usually form an accretion disc of material orbiting faster and faster as it is pulled towards the event horizon. Friction in the accretion disc heats up the material and produces X-rays, which reveal the presence of the black hole to astronomers. In many cases, the accretion disc, combined with strong magnetic fields, channels the flow of matter and energy away from the black hole, in powerful 'jets' that are at right angles to the disc.

If there is no material available to a black hole, then the accretion disc eventually dissipates. The black hole has stopped 'feeding' and there is no material producing X-rays. The black hole has become 'quiescent' or 'dormant' and the only way to detect its presence is through its gravitational effect on nearby objects. The black hole may not be dormant forever. Other material may eventually come into range of the black hole's influence and kick-start the process again. The black hole will become 'active' again. ***AG***

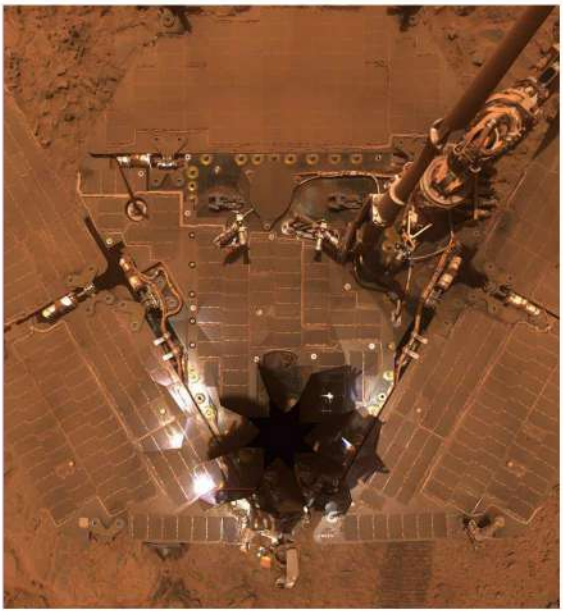
THOMAS GREEN, SALISBURY

WHERE SHOULD YOU STORE YOUR EGGS?

Eggs should be stored at a constant temperature below 20°C, according to the scheme that hands out British Lion marks for eggs laid by hens vaccinated against salmonella. Unless you have a cool larder, it is best to store your eggs in the fridge in their original box to prevent odours from surrounding foods breaking through their porous shells. Don't be tempted to use the egg storage section in the fridge door, because the temperature is too variable with the door's frequent opening. Take the eggs out of the fridge half an hour before cooking to ensure that the shells don't crack when boiling and that they have optimal binding qualities when baking. ***ED***

NEIL GIBBS, SAN DIEGO

WHY CAN'T ROBOTS ON MARS CLEAN THEMSELVES?



Dust has always been a problem when exploring Mars. The thin atmosphere kicks up the planet's fine dust, which then settles on solar panels. This steadily reduces the sunlight reaching the panels, until power drops too low for the spacecraft to function.

The Spirit and Opportunity rovers avoided this fate as the wind periodically blew the dust away. Not every spacecraft is so lucky. NASA's most recent victim was the InSight lander, which lost contact with Earth on 15 December 2022 after four years on the surface.

So why not just include a 'windscreen wiper' to brush away the dust? One of the biggest issues is weight. The mass you can send to another planet is a limit set by the power of your rocket. Every gram counts and adding a cleaning system would mean leaving something else out. So far, the trade-off hasn't been worth it.

Some missions have used existing hardware to try cleaning the panels instead. Using the solar panels' positioning motors to shake the dust loose have met with little success, but InSight did manage to clear some dust using its robotic arm. Counterintuitively, it poured more sand onto the panels. This ran straight off, but not before sending up a bunch of dust already on the spacecraft. The procedure was done during the windiest part of the day, so the lifted material was blown away.

Perseverance and Curiosity bypassed the problem entirely by using radio thermal generators (RTGs) rather than solar panels. These convert the heat given off by a radioactive material, in this case plutonium, into electricity. However, plutonium is hazardous, and more dense than lead. As this makes the craft heavy, plutonium and other radioactive materials are only used for power-hungry missions like the two rovers. ***EP***

GETTY IMAGES X2, NASA/JPL ILLUSTRATION: DANIEL BRIGHT

NATURE'S WEIRDEST CREATURES...

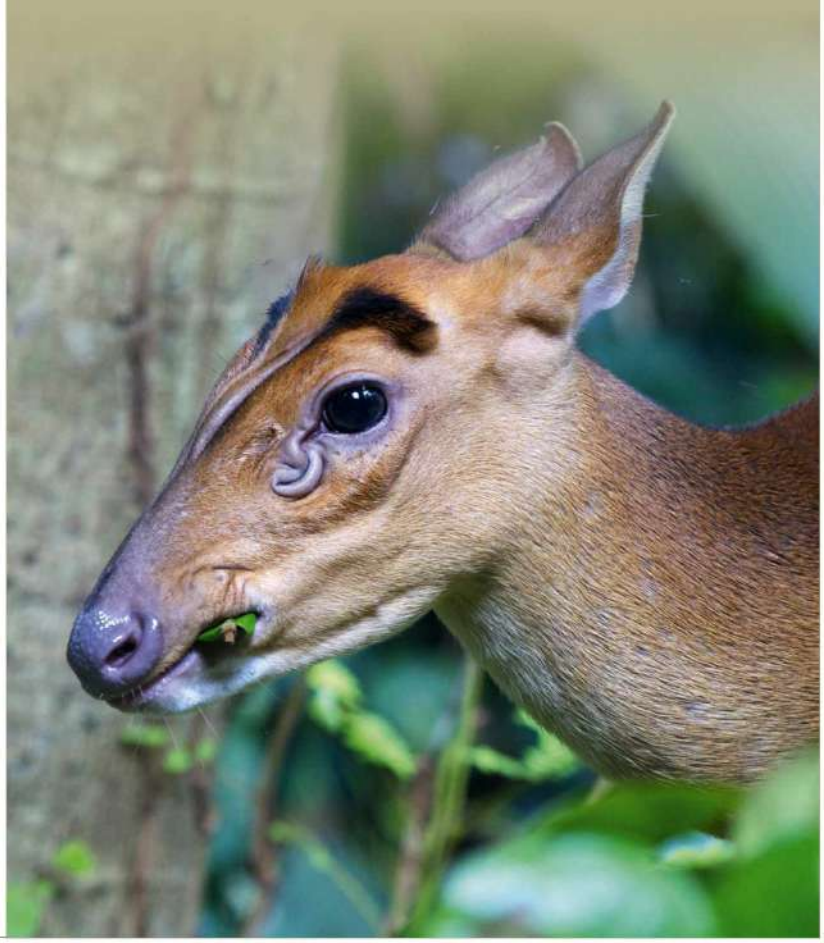
MUNTJAC DEER

Although common in the British countryside, a recent viral video has shed new light on the seemingly bizarre adaptations of the muntjac deer; facial glands that can open so wide, they can actually turn inside out. As the smallest species of deer in the UK, around the height of a small to medium-sized dog, muntjac have two sets of scent glands on their face that grow and swell, like balloons filling with air.

When relaxed, they look like nothing more than small bumps on the deer's face, but to other muntjacs, they are a crucial tool for communication and bonding. As the scent glands expand, they secrete a personalised concoction of chemical compounds that convey information about a deer's sex, age and reproductive status, as well as their overall health, wellbeing, and social hierarchy. A deer will rub their face against a tree (or other object), releasing their scent that acts like a calling card; a message to other creatures in the forest that the muntjac deer is present.

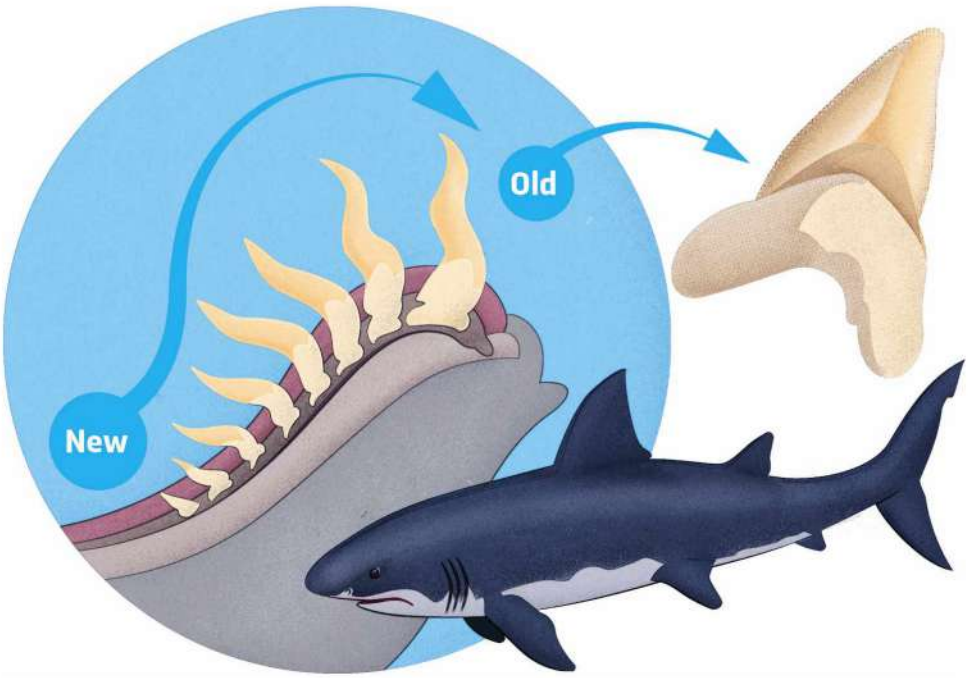
Muntjac also have a variety of vocalisations, ranging from soft grunting noises to something resembling a human scream. They're also known as the 'barking deer' thanks to their loud, resonant (and repeating) bark, which sounds a bit like a loud cough.

This type of bark is unique to muntjacs, and they can be very vocal given their petite size. It's often used as a territorial call, with males barking to attract a female, or to ward off predators. If you live near muntjacs, be warned, this barking can go on for many hours... ***HS***



SAM SIMMONS, VIA EMAIL

HOW DO SHARK TEETH WORK?



Nothing says 'get out of the water quickly' like the sight of a shark's fin and the pulsing theme tune of the *Jaws* movie. Sharks are the ocean's top predator. There are around 500 species, varying in size, diet and behaviour, lurking in waters all over the world. Their teeth come in all shapes and sizes, from the piercing, needle-like teeth of the goblin shark, to the crushing, flattened teeth of the angel shark, and the slashing razors of the great white. An extinct species of mackerel shark, known as the megalodon, had the biggest teeth of any known shark, with triangular gnashers measuring more than 17cm.

When an adult human loses a tooth, it's game over and a trip to the dentist is needed to have an implant fitted. Sharks, however, can replace lost teeth throughout their life. They need to. Ground sharks, which are the largest order of sharks, including hammerheads and tiger sharks, lose around 35,000 teeth in a lifetime. They frequently fall out or become damaged when the fish are grappling with their prey, but the sharks are blessed with multiple rows of teeth, which are lined up, one behind the next. When a tooth falls out, the corresponding tooth in the row behind simply moves forward to take its place. And the one behind that one moves forward to take its place. And so on. It's like a conveyor belt that's made of teeth.

Working with catsharks, scientists have discovered pockets of stem cells inside the sharks' mouths, which can divide to produce new, more specialised cells, which ultimately form the teeth that are needed to keep the conveyor belt stocked. The genes controlling this process have similar counterparts in humans, so now scientists are wondering if they could tweak the activity of these genes in people, to help us regrow lost teeth too. ***HP***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

BBC WORLD SERVICE CROWD science

WHY DO I GET SO JEALOUS?

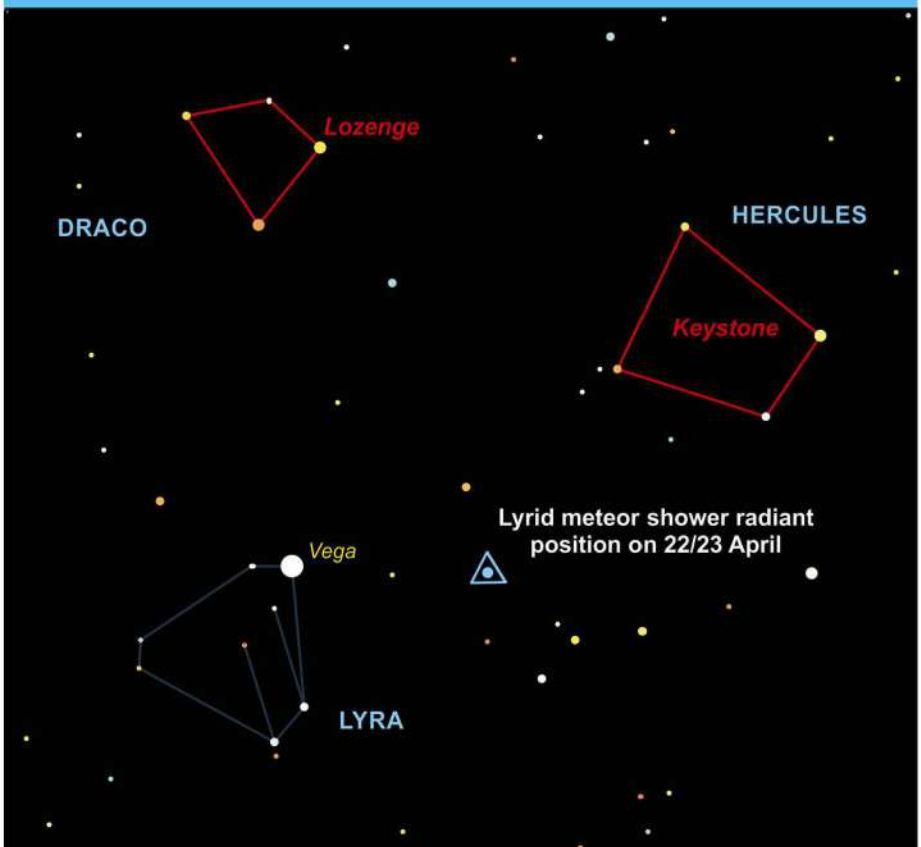
Not to be confused with envy, which is coveting another person's status or belongings, jealousy – aka the green-eyed monster – is the unpleasant range of feelings you experience when you sense that your relationship with someone is under threat from a third party. Usually, it occurs in a romantic or sexual context – for example, if you see your boyfriend flirting with someone else – but it can also play out in the context of friendships or in family situations.

If you experience a lot of jealousy, perhaps worrying that your partner fancies someone else, or you feel an urge to check their text messages for signs of disloyalty, it might be because you have low self-esteem, or because you tend to feel insecure in your relationships (psychologists call this having an anxious-attachment style). There's also research showing that you're more likely to feel jealousy toward potential rivals who happen to enjoy the attributes that you most admire or desire.

If your jealousy is causing you problems, it's worth reminding yourself that it's a normal human emotion – and on the plus side, it shows that you care about your partner or friend. If you share your feelings with them, they might even be touched to know how much they matter to you. If your feelings of jealousy get of hand and begin to harm your relationship, consider exploring ways to boost your own sense of self-worth and security. By learning to love yourself more, you will likely find that your jealousy naturally fades away. *CJ*

GETTY IMAGES X2, ILLUSTRATIONS: DANIEL BRIGHT, PETE LAWRENCE

ASTRONOMY FOR BEGINNERS



LYRID METEOR SHOWER

WHEN: MID- TO LATE-APRIL

The Lyrid meteor shower is active between 16-25 April, with peak rates expected on the night of 22/23 April. On this night, if conditions are perfect, you'll be able to see around 18 meteors per hour.

Meteor shower activity is quantified by Zenithal Hourly Rate (ZHR), measured in meteors per hour. A shower happens when Earth passes through the wide debris stream of a comet. Usually sparsely populated, streams can become denser towards their core. Particles the size of a grain of sand from within the stream vaporise when they enter Earth's atmosphere, producing streaks of light we call meteors.

The particles are on parallel orbits around the Sun. When they enter our atmosphere, our perspective makes it look as if they emanate from a small area of sky called the shower 'radiant'. A shower's ZHR assumes an overhead radiant, as well as perfect sky conditions. Anything short of these requirements lowers the visual hourly rate, which is the actual number of meteors seen.

Over time, the radiant drifts slowly against the stars, our chart showing where it will be on peak night. For a meteor to be a Lyrid, it must appear to be coming from the radiant position. As darkness falls, the star Vega is low above the northeast horizon, gradually climbing in altitude to be virtually overhead before dawn.

To get the best views, find a dark area away from streetlights, and avoid looking at artificial lights (including mobile phones!). Allow 20 minutes for your eyes to fully adapt. Look approximately two-thirds up the sky (60° altitude), slightly away from the radiant position – trails will appear longest around 90° from the radiant. No Moon interference in 2023 means this year's Lyrid peak is very favourable. Unfortunately, this isn't the case for the Eta Aquariid shower, which peaks on the morning of 6 May. ***PL***

EDDIE RACOUBIAN, LEBANON

WHY IS LITHIUM SO RARE IN THE UNIVERSE?

Presently, astronomers are unsure why lithium is as rare as it is in the Universe. The 'standard' model of the Big Bang, using what we know of nuclear physics, can accurately predict the abundances of the chemical elements that were formed between about 100 to 1,000 seconds after the Big Bang. However, although the standard model precisely predicts the primordial hydrogen and helium abundances, it overpredicts the measured primordial abundance of lithium by a factor of three to four. So, either the predictions are inaccurate (and the measurements are correct), or the predictions are accurate (and the measurements are wrong).

Scientists have investigated possible solutions to this so-called 'lithium problem'. One possibility is that there is something missing in our understanding of nuclear physics — leading us to overestimate the lithium abundance. However, recent research seems to completely discount this possibility.

Perhaps we don't fully understand the processes going on inside stars – processes which could be destroying lithium out of sight. Although astronomers know that cooler stars have deep convection zones which can drag lithium to the star's core and destroy it, and that binary stars, or those with planetary systems, can also alter the primordial abundance of lithium, these processes do not seem to be enough to account for the discrepancy. However, some scientists still maintain that there must be other, unknown ways to destroy lithium in the Universe.

Another possible solution to the lithium problem is that there is entirely new physics of which we are unaware. Perhaps mysterious dark matter had an unappreciated effect on the production of elements in the very early Universe. Or perhaps the fundamental constants on which physics is based have not remained constant throughout cosmic time. There are numerous such theories being considered to solve the problem. But, at present, the odd rarity of lithium in the Universe is a complete mystery. ***AG***

MYTHBUSTERS

CAN WHAT I WEAR REALLY AFFECT MY MOOD?

Dubbed 'part fashion, part mindfulness', dopamine dressing is the TikTok trend that encourages people to choose clothing that matches their desired mood. So, if we opt for colourful clothing over the drab and dreary, we'll get a boost of dopamine and feel happier.

Dopamine, as a neurotransmitter, is involved in several brain functions including the forming of emotions. It's not the only molecule that can affect how we feel – serotonin, oxytocin and various endorphins interact with dopamine to give rise to our mood. But dopamine does play a fundamental part in our brain's reward system.

As to whether our outfit choice can offer a dopamine boost, to put it plainly, we don't know – there is no study that has asked participants to change into brightly coloured clothes while monitoring the dopamine levels in their brain. But as far as the concept goes, there are studies that show a relationship between the clothes we wear and how we act and feel.

In one study, people photographed wearing a red or black T-shirt were viewed as being more attractive than those wearing any other colour. Wearing red can also lead to better physical performance. A review of football matches over the last 55 years showed that teams with a red kit consistently played better in home games than any other kit colour.

One study showed that wearing an outfit that has an association with a profession, like a doctor's white coat, improves cognitive processes. Termed 'enclothed cognition', this might also be why wearing gym clothes makes us more likely to exercise. While formal suits make a person act with more dominance, when it comes to performance, comfort is arguably more important – students taking exams fared better when they were wearing comfier, less formal clothes.

Those who spend their days pursuing creative endeavours might want to try wearing green, as viewing the colour has been linked to better creative performance. The colour green has also been found to evoke feelings of relaxation, likely because it reminds us of nature. Yellow, and its suggestions of summer and warmth, can bring a viewer happiness, energy and excitement, though it's not known if these feelings occur when wearing the colour.

There are some problems with studying associations between colour and emotions, namely that our opinions are closely linked with our culture. In the UK, we may associate the colour black with sadness because it's what we wear to a funeral, but mourners wear white at funerals in China. We also can't say for certain that everyone sees colour the same, as anyone who saw 'the dress' on social media in 2015 can attest. ***AA***

KIM WHEELER, VIA EMAIL

HOW INCOGNITO IS INCOGNITO MODE ON YOUR INTERNET BROWSER?

Not very. When you turn on private mode or launch an incognito browser window, it's like starting from scratch on a new computer. There will be no cookies to help your browser, so you'll have to re-login to websites that need your details. When you're done, the browser will delete the new cookies and temporary cache files and keep no history of your activity. As far as your computer is concerned, there is no record of your browsing, apart from any files you downloaded, or bookmarks saved.

But that's not the whole story. For your computer to connect to the internet, it must go through your router, and the router can monitor all web addresses that you visit. This will happen regardless of whether the user turns on private mode of the browser.

Even while you are browsing using incognito, you leave digital footprints all over the web. Cookies may be deleted after you're done, but while you're browsing, the websites are happily storing information about your activities. If you login to any site while in private mode, you've given the game away instantly. You are identified by the site and all your activities will be tracked as normal. Your searches will be recorded, along with your browsing activities on any social media sites, and your purchases will all be stored. Through temporary cookies, your activities can be linked across multiple accounts and profiles, gathering more data about you.

So, you decide not to login to any site. You're still tracked through your computer's IP address, which can locate your approximate region. It's a method used in sales to figure out whether an anonymous potential purchaser has been clicking around. The IP address is tracked, and emails are sent with tempting offers to try and convert that interest into a sale. Combine the IP address with device type and browser details, and it's possible to figure out who you are, regardless of whether you've given your name. Some browsers are trying to block this, but websites keep finding ways to track you. ***PB***

DAVID CURTIS, NEWCASTLE

WHY CAN'T YOU EAT OR DRINK BEFORE A GENERAL ANAESTHETIC?

When you have a general anaesthetic, you will usually be asked not to have anything to eat or drink for a period of time before. Although it might feel cruel on top of the stress of undergoing a procedure, it's for your own safety.

When the general anaesthetic is used, your body's reflexes are temporarily stopped. If your stomach has any food and drink in it, there's a risk of vomiting or bringing up food into your throat. If this happens, the food could get into your lungs and affect your breathing, as well as causing damage. Inhaling vomited stomach contents into your lungs is called 'aspiration', and it can lead to a dangerous infection.

The amount of time you have to go without food or drink before you have your operation will depend on the type of operation you're having. However, it is usually at least six hours for food, and two hours for fluids. You'll be told how long you must not eat or drink for before your operation.

Unfortunately, even chewing gum – including nicotine gum – should be avoided during this fasting period, and soups and sweets should also not be consumed. You may also be advised to avoid certain types of fluids, such as milk, or tea and coffee with milk added to them. Clear fluids, such as water, are usually allowed until two hours before.

While it might feel annoying to avoid food, you must follow the guidelines. If you eat or drink before your surgery, your operation can be postponed or even cancelled because of the risks involved. ***NM***

QUESTION OF THE MONTH

HURLEY, VIA EMAIL

PROPOSED FUSION POWER PLANTS WILL GENERATE NO RADIATION. SO WHY DOES THE SUN, WHICH ALSO USES FUSION, PRODUCE SO MUCH?

Energy can be liberated from atomic nuclei in several ways via fission or fusion. In fission, heavy nuclei are broken apart to create smaller nuclei, releasing energy in the form of photons. The problem with fission is that often the lighter products of the process are 'radioactive isotopes'. These are unstable nuclei that spontaneously decay into other elements by releasing electrons, positrons, helium nuclei, or very energetic gamma-ray photons. These particles, often called 'radiation', are hazardous to life.

In fusion, lightweight atomic nuclei liberate energy when they combine to form heavier elements. Deep in the Sun's core, at high temperatures and pressures, hydrogen nuclei are fused to make helium nuclei. This releases large amounts of energy in the form of neutrinos and gamma-ray photons, as well as the kinetic energy of the helium nuclei. Each high-energy gamma-ray produced in the Sun's core, on its long journey to the solar surface, is converted into millions of visible light photons. That is the source of the 'radiation' we receive from the Sun. So, the Sun produces dangerous radiation, but only electromagnetic radiation — and none of the nasty radioactive by-products associated with fission reactions.

Fusion reactions produce, pound for pound, more energy than fission reactions. However, fusion reactions require extremely high temperatures and pressures to get started. This is why we have not yet fully solved the production of clean and efficient fusion energy. ***AG***

WINNER

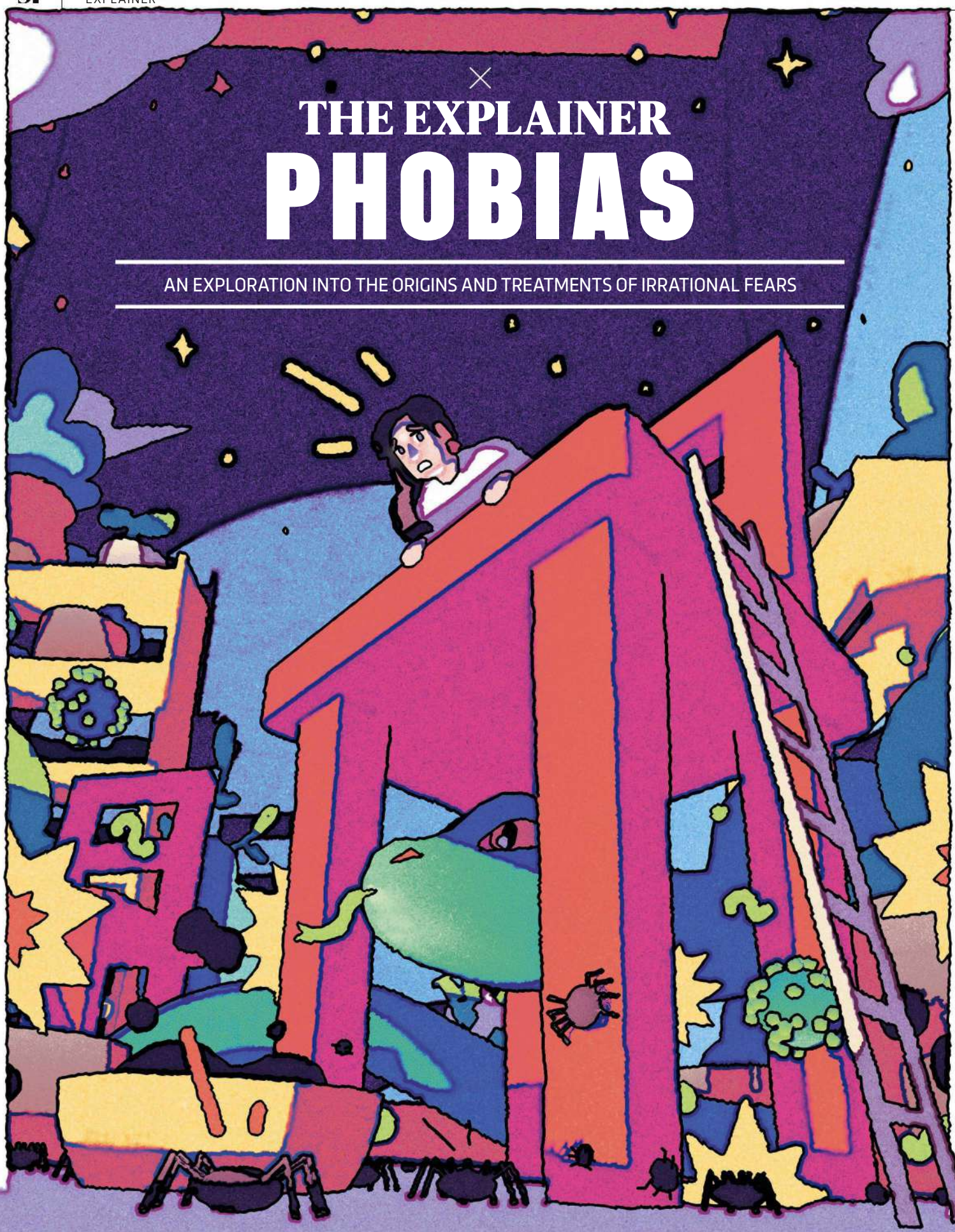
The winner of next issue's *Question Of The Month* wins **two books from Pelagic Publishing**, worth £41.99. *Invisible Friends* by Jake Robinson presents an engaging account of the importance of microbes to all life, while *Reflections Underwater* by Oded Degany is an exploration of coral reefs, complete with stunning photography. **pelagicpublishing.com**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X3 ILLUSTRATIONS: DANIEL BRIGHT

THE EXPLAINER
PHOBIAS

AN EXPLORATION INTO THE ORIGINS AND TREATMENTS OF IRRATIONAL FEARS



ILLUSTRATIONS: KYLE SMART

In the context of mental health, a phobia is far more serious than a mild aversion. Many of us dislike flying, or giving a talk in front of our colleagues, and we might not be too happy if a large, slobbery dog, no matter how gentle, came bounding toward us. But as long as we can tolerate these kinds of situations without too much distress, and our lives aren't adversely affected, then we haven't got a phobia for any of these situations as such.

In contrast, people diagnosed with a relevant phobia would experience an intense, extremely unpleasant fear reaction that could be overwhelming. So much so, that it might interfere with their day-to-day lives. Flying phobias, social phobias, and a fear of dogs (even cute ones) are common examples – but there are dozens of others, including some quite bizarre examples, such as trypophobia, which is a fear of clusters of holes (like you get in crumpets), sedatephobia (a fear of silence) and gerascophobia (a fear of ageing).

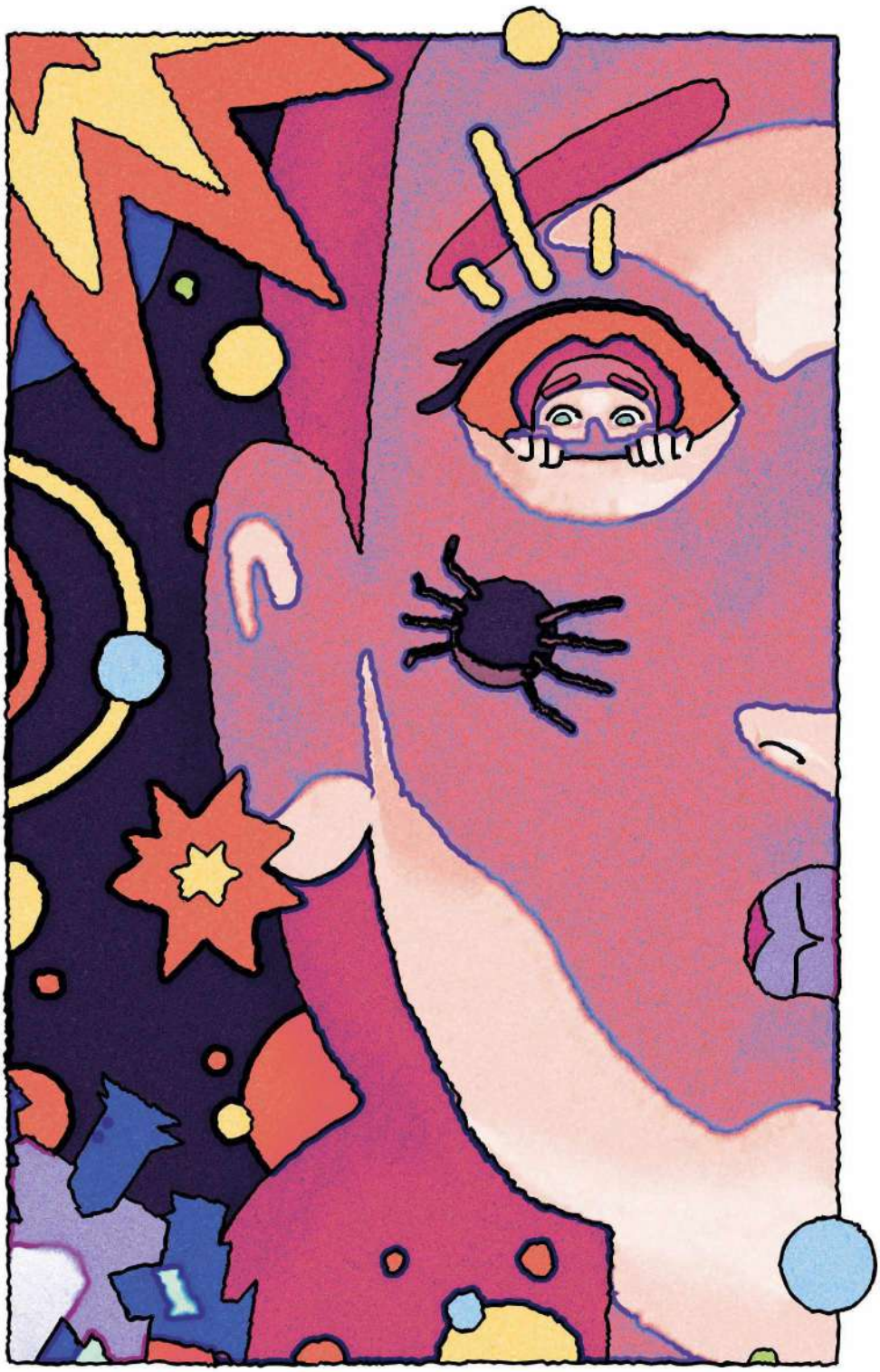
ARE PHOBIAS A DISORDER?

Phobias are a formal psychiatric diagnosis in the anxiety category. To be diagnosed, you'd need to have experienced a phobia for at least six months, and your fear reactions to the focus of your phobia would need to be out of proportion to the danger you were in.

Psychiatry recognises five main categories of 'specific phobia' (between 3 to 15 per cent of people will develop one of these at some point in their lives): animal phobias (spiders and snakes are common examples); environmental phobias (such as heights or deep water); blood/injection phobias (think needles or the mere sight of blood); situational phobias (such as bridges or dentists); and finally an 'other' category that covers almost everything else, such as a fear of swallowing or being sick.

Aside from the specific phobias, there's 'social phobia' (also known as 'social anxiety' which affects up to 12 per cent of people at some point) and agoraphobia (affecting around 1 per cent of people). A lot of people misconceive agoraphobia as being a fear of going outside, or of open spaces, but actually it's more accurately described as a fear of being in any kind of situation where escape might be impossible, so it could manifest as a fear of being stuck in traffic, for instance.

"Phobias are a formal psychiatric diagnosis in the anxiety category"



HOW PHOBIAS AFFECT THE BRAIN

There is a network of brain structures, known as the limbic system, that is involved in fear and anxiety and the acquisition of phobias. Perhaps the most important structure is the amygdala (there's one each side of the brain), which plays a significant role in learning fears. Imagine as a kid, hearing a buzzing sound and then getting stung by a wasp – your amygdala would play a key role in helping you learn an association between the buzzing sound and the future risk of getting stung. If the fear is intense enough, the amygdala will communicate with other parts of the limbic system such as the hypothalamus, to help initiate the fight or flight response, and the hindbrain (including the brainstem), to trigger a startle response such as quickly withdrawing your stung hand. It's the activation of the fight or flight response that can make a phobic reaction so overpowering – think rapid heart rate, fast breathing, nausea, panic and sweating.

ILLUSTRATIONS: KYLE SMART

HOW DO YOU DEVELOP A PHOBIA?

Some phobias develop out of natural aversions. For instance, a dislike of spiders, or of heights, can intensify over time until the point that it becomes a phobia. At first, the experience might be fairly mild. Imagine seeing a spider, finding it scary and wanting to get away from it. But over time, if that aversion became a preoccupation and it started to cause problems in life, then it would have become a diagnosable phobia.

For instance, imagine finding it difficult to go to sleep at night out of fear that there could be a spider lurking under the bed, or in the shadows. Or finding the sight of a spider in the corner of the office or classroom so distressing that you had to leave the room. Similarly with heights – finding a high, precarious position uncomfortable is common and understandable, but feeling so scared of heights that you can't work on a high floor in a tower block, or can't go on a school geography trip to the cliffs, would suggest a phobia.

Other phobias can emerge more dramatically – they might follow a particularly scary, unpleasant incident, such as a painful wasp sting as a child leading to a phobia. Avoidance of the source of a fear will typically fuel a phobia. For instance, if you always avoided spiders, or heights, or wasps, you'd never get to experience the fact that they're not usually a threat, and so your fear of them could fester, and then grow over time.

IS IT POSSIBLE TO 'INHERIT' A PHOBIA?

You can't literally inherit a specific phobia through your genes, but some people seem to be more predisposed to develop phobias than others – and this tends to run in families. To return to the childhood wasp sting, for many people this would soon be forgotten, but for those with a more anxious, fearful temperament – perhaps at least partly inherited via their genes – it would be more likely to develop into a full-blown phobia.

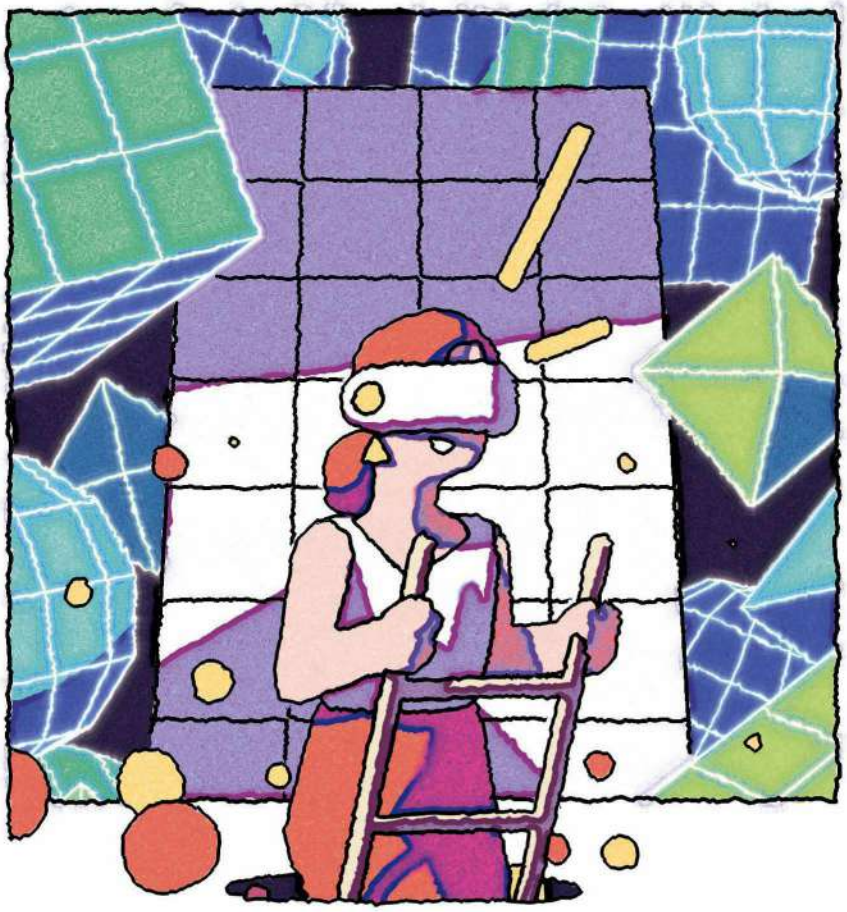
Part of this vulnerability might be related to the way that some people, but not others, actually begin to fear their fearful reaction to certain triggers (essentially, they develop a fear of fear, finding it really scary and unpleasant).

To an extent, it's also possible to acquire phobias from others. If you are raised in a family that's intensely frightened of flying, for example, then it's more likely that you too would develop your own fear of flying (and of course this 'modelling', as it's known, will also interact with genetic vulnerabilities).

Bear in mind, too, that it seems to be especially easy and common to develop phobias for things that would have threatened the survival of our ancestors – such as heights and snakes. As a rule, fear in moderation is useful and helps keep you alive, but it's when it gets out of hand that it becomes a phobia.

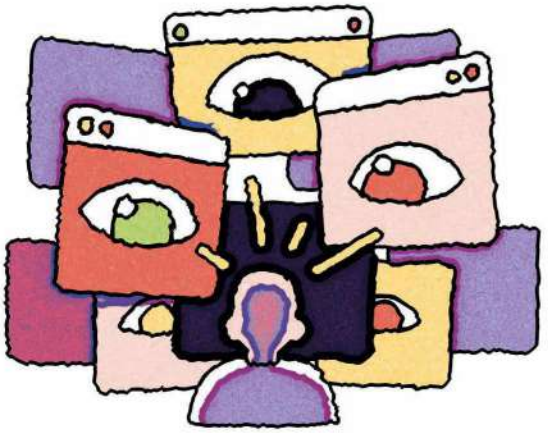
"It seems to be especially easy and common to develop phobias for things that would have threatened the survival of our ancestors"

"Cutting-edge interventions use virtual reality or augmented reality to help you overcome a phobia"



WILL PHOBIAS EVER GO AWAY?

Phobias can sometimes abate by themselves, and they are also highly treatable. Popular approaches to treatment have evolved over time. Psychoanalytic methods that see phobias as an outward expression of hidden emotional problems have largely fallen out of fashion. These days, you are more likely to be taught relaxation techniques to help you gain control over your fear reaction, and this will be combined with gradual exposure to the focus of your phobia, so that you can learn that it's not as dangerous as you think. Cutting-edge interventions use virtual reality or augmented reality to help you overcome a phobia – these methods allow fine control over the intensity of the source of your fear (for example, by altering the size of a spider, or the height of a ladder) and act as a useful stepping stone on the way to confronting the fear for real. At the experimental stage are investigations using beta-blockers and other compounds to interfere with the brain-basis of acquired fears.



PHOBIAS AND THE MODERN WORLD

In theory, it's possible to develop an intense fear of pretty much anything, and in different eras the focuses of people's fears have changed. For example, in the early days of train travel, there was a lot of interest in various forms of train phobia ('siderodromophobia'), such as fear of missing them – psychologist Sigmund Freud was reportedly a sufferer – or of the physical sensations they cause. In more recent times, there's been much talk of 'nomophobia', which is a fear of being without your mobile phone, either because it's run out of juice or because you've lost it.

Relatedly, people talk today of a 'fear of missing out' (FOMO) which can be triggered by a lack of access to social media, or other forms of information. Sometimes long-known phobias can manifest in new ways. For instance, there's 'scopophobia' – the fear of being stared at – which has acquired a new relevance in the age of Zoom meetings. Another contemporary phobia that's probably on the milder end of the spectrum, is agmenophobia or the fear that you've chosen to join the wrong queue – usually the slow one.

DR CHRISTIAN JARRETT

Christian is a psychologist, writer and editor. His latest book is Be Who You Want: Unlocking The Science Of Personality Change *(£11.99, Robinson).*

FIVE UNUSUAL PHOBIAS

Genuphobia

The fear of knees (*genu* is Latin for knees), which can manifest in different ways, such as an irrational fear of the sight of them, or even intense worries about sustaining a knee injury or kneeling.

Bambakomallophobia

The fear of cotton wool (the formal term is made up of the Greek words for cotton and wool). "I feel sick at the thought of the very particular way in which it would feel and squeak between my fingers," sufferer Chris Hall told *The Guardian* in 2019.

Pogonophobia

The fear of beards (*pogon* is Greek for beard) and is reportedly more common in women than men. In some cases, a little stubble is all it takes to set off the phobia. The late British prime minister Margaret Thatcher was reportedly a sufferer.

Haphephobia

The fear of being touched, even by family or friends. It's not a skin sensitivity problem, rather it's an aversion to the idea of being touched. The fictional character Christian Grey, from *Fifty Shades Of Grey*, is described as suffering from this phobia.

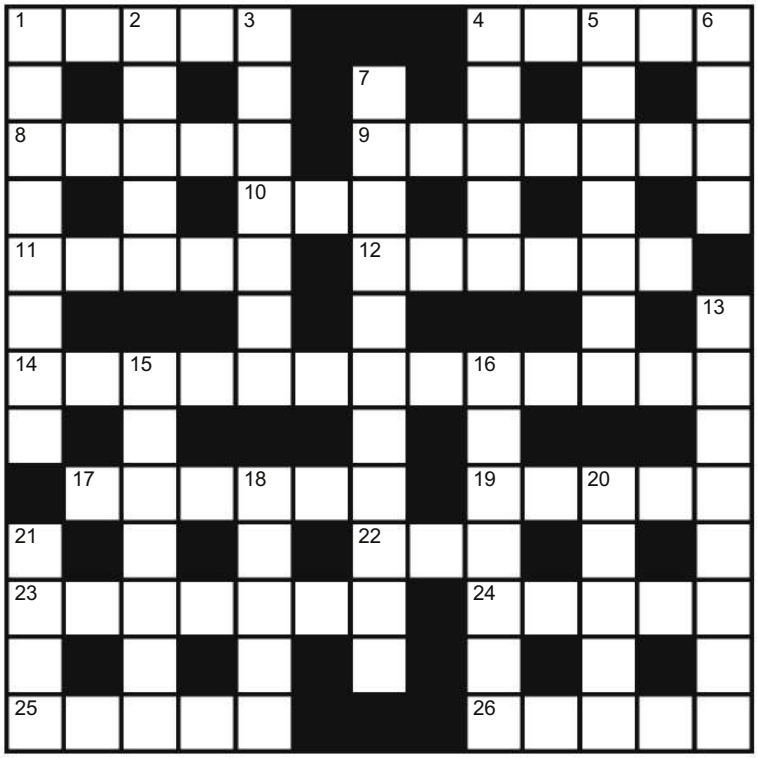
Trypophobia

The fear of holes, from the Greek word for holes *trýpa*. For people with this phobia, cheese, crumpets, or anything featuring a cluster of holes can be enough to trigger a fear reaction. SF

ILLUSTRATIONS: KYLE SMART

CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Cargo's about to be removed in brawl (5)
4 The best thing for strawberries? (5)
8 Cosmetic is a shade foreign (5)
9 Writer having set drama first in infantile area (7)
10 A politician's current (a bit) (3)
11 Brush, not having a plant (5)
12 Inactive US city shelter (6)
14 Scientific expression for complicated time at school (9,4)
17 Push to broadcast result (6)
19 Using voices, losing hard colour (5)
22 Type of silkiness (3)
23 Jealous character to return greeting (7)
24 Comedian in the pack (5)
25 Circuits, at point, failing (5)
26 Has been sheltering from French paddles (5)

DOWN

1 Violence for changes around English metropolis (8)
2 Indicator shows gold in egg formation (5)
3 The initial cause for crime (7)
4 Vessel caught stern Republican in the middle (5)
5 Criticises putting river around wide area (7)
6 Herb that makes money (4)
7 Request software program (11)
13 Begs rascal to rewrite roles (8)
15 Cut work on Sunday inside law establishment (3,4)
16 Tetanus making rugby player talk at length (7)
18 Lethal venom has to reduce by fifty per cent (5)
20 Slowed down, not initially collected in the garden (5)
21 One's not bright enough to make dessert (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

BRAIN FINGERPRINTS

Scans of your grey matter might be able to predict your future mental health.

GETTY IMAGES

PLUS

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We know we need to exercise to keep our bodies healthy, but did you know our satisfaction with our relationships can also keep us in peak condition as we age?

ANXIETY

Understand what causes it and find out how to help ease its effects.

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POPCORN SCIENCE

Can we feel others' emotions?

Mantis, from *Guardians Of The Galaxy*, is an empath. Do we feel the same way, too?

by **STEPHEN KELLY**

There is a scene in *Guardians Of The Galaxy Vol 2*, the Marvel movie released in 2017, where the character of Mantis – an alien played by Pom Klementieff – touches Chris Pratt's Peter Quill on the hand. "You feel love!" she tells him, her face beaming. "I guess, yeah," he replies, nervously. "I feel a general, unselfish love for just about everybody…" "No! Romantic, sexual love," she says, before pointing a finger at Quill's teammate, Zoe Saldana's Gamora. "For her!"

Some superheroes have super-strength. Others fly. Mantis's superpower is a souped-up version of empathy, meaning that she can touch someone and feel their emotions as though they were her own. Yet according to neuroscientist Dr Dean Burnett, author of new book *Emotional Ignorance*, this isn't quite as fantastical as it sounds. In fact, it's merely an extreme version of something we already do.

"Humans have evolved – primates as well – with mirror neurons that react when you see someone doing something, not when you do it," he explains. "We have evolved the ability to see other people's actions, their physical characteristics and their movements, and our brains have an elaborate system that's fed into the planning part of the brain that goes, 'Right, so they did this. If I did that as well, I would be able to learn this skill.' It's how we learn by observation, and that's a really complex, evolved system, which connects the motor cortex, the mind map, the body map, the other regions, and our actions."

But at some point in our evolution, this network became fundamentally connected to the granular part of the insular cortex, which is a big part of the emotion system.

"So now, whenever someone is feeling emotion, someone else has loads of different cues: the colour of their face, their expression, their stance, their posture – all of that is a big part of an emotional expression. By linking that to our emotional system, our brain recognises that someone is angry or overjoyed and that leaks into our emotional system. Therefore we see someone else's emotional state, and feel it ourselves."

Burnett is sceptical, however, about the idea of real-life Mantis-style empaths, who tend to claim that they have a greater empathic sensitivity than others.

"I don't know of any variant of human who has a special ability in this area," he says. "People can call themselves an empath, but it's not a recognised scientific title. Plus, it seems pretty egotistical. Everyone has empathy, to a degree, even psychopaths – they can recognise other people's emotional state and manipulate it."

Unsurprisingly, empathy tends to be stronger for people you care about in some way. This, of course, can lead to disturbing consequences, particularly when it comes to empathy for "ingroups and outgroups", as Burnett puts it – essentially, people you identify with (ingroups) compared to those you find it harder to relate to (outgroups). But there's also an evolutionary advantage to curbing our empathetic abilities – especially before it can reach the levels of Mantis, who feels other people's emotions so strongly she can become overwhelmed by them.

"As a tribe, as a social species, we wouldn't be able to function," says Burnett. "In the olden days, on the African savannah, if you saw someone break their leg and roll around in agony, you'd say, 'Oh, God, that looks awful' and feel bad for them. But if you felt that exact same pain yourself, you'd be incapacitated. It would mean that, while running from a predator, if it took out one of you, then suddenly it's got all of you. Empathy has to be a reflection of an emotional state, not the actual thing." **SF**

VERDICT

We all feel empathy, so Mantis's skills aren't that outlandish. But luckily for us, we don't tend to feel overwhelmed by others' emotions, like she does.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATION: JASON LYONS

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

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